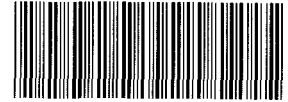


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ANNUAL ENVIRONMENTAL MONITORING REPORT
U. S. DEPARTMENT OF ENERGY, ROCKY FLATS PLANT
January Through December 1986

ENVIRONMENTAL MANAGEMENT SECTION

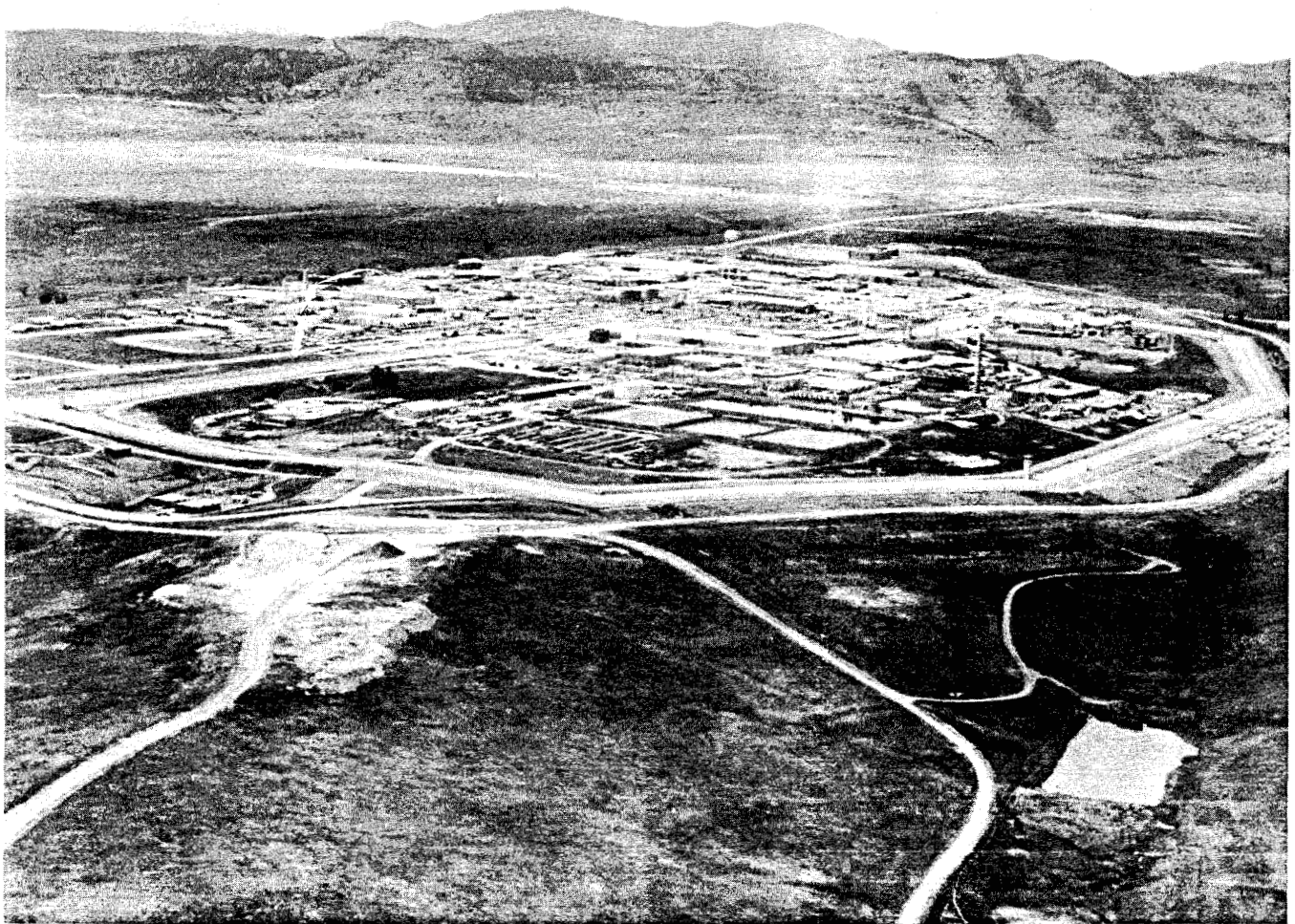
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ROCKY FLATS PLANT VIEWED FROM THE EAST

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ABSTRACT

This report documents the environmental surveillance program at the Rocky Flats Plant, as conducted by Environmental Management Section of the Health, Safety and Environment (HS&E) Operations Management Branch. Sample analyses are performed by the Health/Environment Analytical Laboratories (H/EL) of the Health, Safety and Environment Department and by the General Laboratory of the Quality Engineering and Control Department. The report includes an evaluation of plant compliance with all appropriate guides, limits, and standards. Potential public radiation dose commitments were calculated from average radionuclide concentrations measured at the plant property boundary and in surrounding communities. The radioactive and non-radioactive effluents from the Rocky Flats Plant meet the appropriate guides and standards and represent no measurable adverse environmental effects from the operation of the plant during calendar year 1986. The estimated potential radiation doses to the public from plant effluents are below Department of Energy and Environmental Protection Agency dose standards and are well below background dose levels experienced in this region from natural and other non-Rocky Flats Plant sources.

ANNUAL ENVIRONMENTAL MONITORING REPORT

U. S. DEPARTMENT OF ENERGY, ROCKY FLATS PLANT

January Through December 1986

I INTRODUCTION

The Rocky Flats Plant is a government-owned and contractor-operated facility. It is part of a nationwide nuclear weapons research, development, and production complex administered by the Albuquerque Operations Office of the U. S. Department of Energy (DOE). The prime operating contractor for the Rocky Flats Plant is the North American Space Operations Group of Rockwell International.

The Rocky Flats Plant is located at 105°11'30" west longitude and 39°53'30" north latitude in northern Jefferson County, Colorado. The plant-site consists of 2,650 hectares (6,550 acres) of federally owned land. As shown in Figure 1, major plant structures are located within a security-fenced area of 155 hectares (384 acres). The plant is approximately 26 kilometers (16 miles) northwest of downtown Denver and is almost equidistant from the cities of Boulder, Golden, and Arvada (see Figure 2). Demographic estimates for 1980 are shown in Figure 3. There is a population of approximately 2 million people within a 50-mile radius of the plant.

The plant is a key DOE facility that produces components for nuclear weapons; therefore, its product is directly related to national defense. The plant is involved in fabricating components from plutonium, uranium, beryllium, and stainless steel. Production activities include metal fabrication and assembly, chemical recovery and purification of process-produced transuranic radionuclides, and related quality control functions. Research and engineering programs supporting these activities involve chemistry, physics, materials technology, ecology, nuclear safety, and mechanical engineering.

Approximately 134 structures on the plantsite contain approximately 248,100 square meters (2.67 million square feet) of floor space. Of this space, major manufacturing, chemical processing,

plutonium recovery, and waste treatment facilities occupy about 148,600 square meters (1.6 million square feet).

The remaining floor space is divided among laboratories, administrative, utility, security, warehouse, storage, and construction contractor facilities, and occupies about 99,000 square meters (1.07 million square feet).

All of the plant heating requirements are met by in-plant steam boilers that normally use natural gas and are capable of using fuel oil. During CY 1986, approximately 17.0 million cubic meters (601 million cubic feet) of natural gas were used. Three million liters (797,000 gallons) of fuel oil were used during 1986.

Raw water is purchased from the Denver Water Board and is drawn from Ralston Reservoir and the South Boulder Diversion Canal. The Rocky Flats Plant used approximately 495 million liters (131 million gallons) of water during 1986.

The piedmont of the Front Range of the Rocky Mountains rises 8 kilometers (5 miles) west of the site and crests at the Continental Divide, which is 32 kilometers (20 miles) from the plant. The natural environment of the plantsite and vicinity is influenced primarily by the Front Range of the Rocky Mountains and the site elevation, which is 1,829 meters (6,000 feet) above sea level. The surficial geology of Rocky Flats consists of a thin layer of gravelly topsoil underlain by a 6- to 15-meter (20- to 49-foot) thick layer of coarser, clayey gravel. This is underlain by a bedrock structure upon which plant building foundations are supported. Area hydrology is influenced by the topsoil, which consists of gravelly and highly permeable alluvium. Water retention in the soil is poor, and vegetation in the area is sparse. Cacti, spanish bayonet, and grasses representative of a mixed short- and mid-grass plain, constitute the

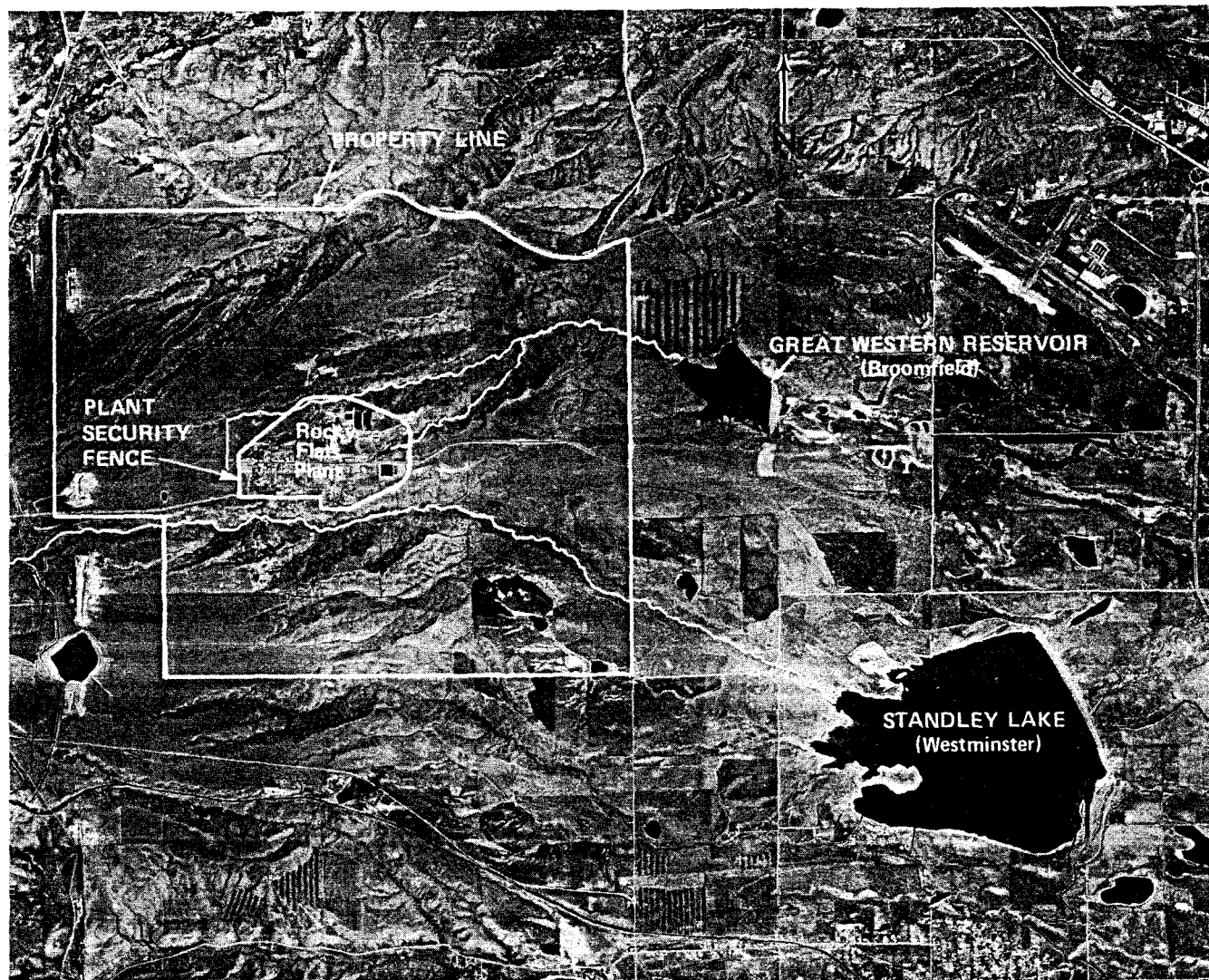


FIGURE 1. Aerial Photograph of the Rocky Flats Plant and Immediate Vicinity

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main ground cover. Introduced Eurasian weeds also make up part of the flora. Cottonwood trees grow adjacent to watercourses.

The climate at Rocky Flats is characterized by dry, cool winters with some snow cover and warm, somewhat moist summers. There is considerable clear-sky sunshine, and the average precipitation and relative humidity are low. The elevation of the plant and the major topographical features of the area significantly influence the climate and meteorological dispersion characteristics of the site.

Winds at Rocky Flats, although variable, are predominantly northwesterly, with stronger winds occurring during the winter. During 1986, approximately 54 percent of the winds had a westerly component.

Annual average precipitation at the Rocky Flats Plant is slightly over 38.5 centimeters (15.16 inches). The maximum annual precipitation recorded over a 24-year period was 63.17 centimeters (24.87 inches) in 1969. Typically, more than 80 percent of the precipitation falls as rain

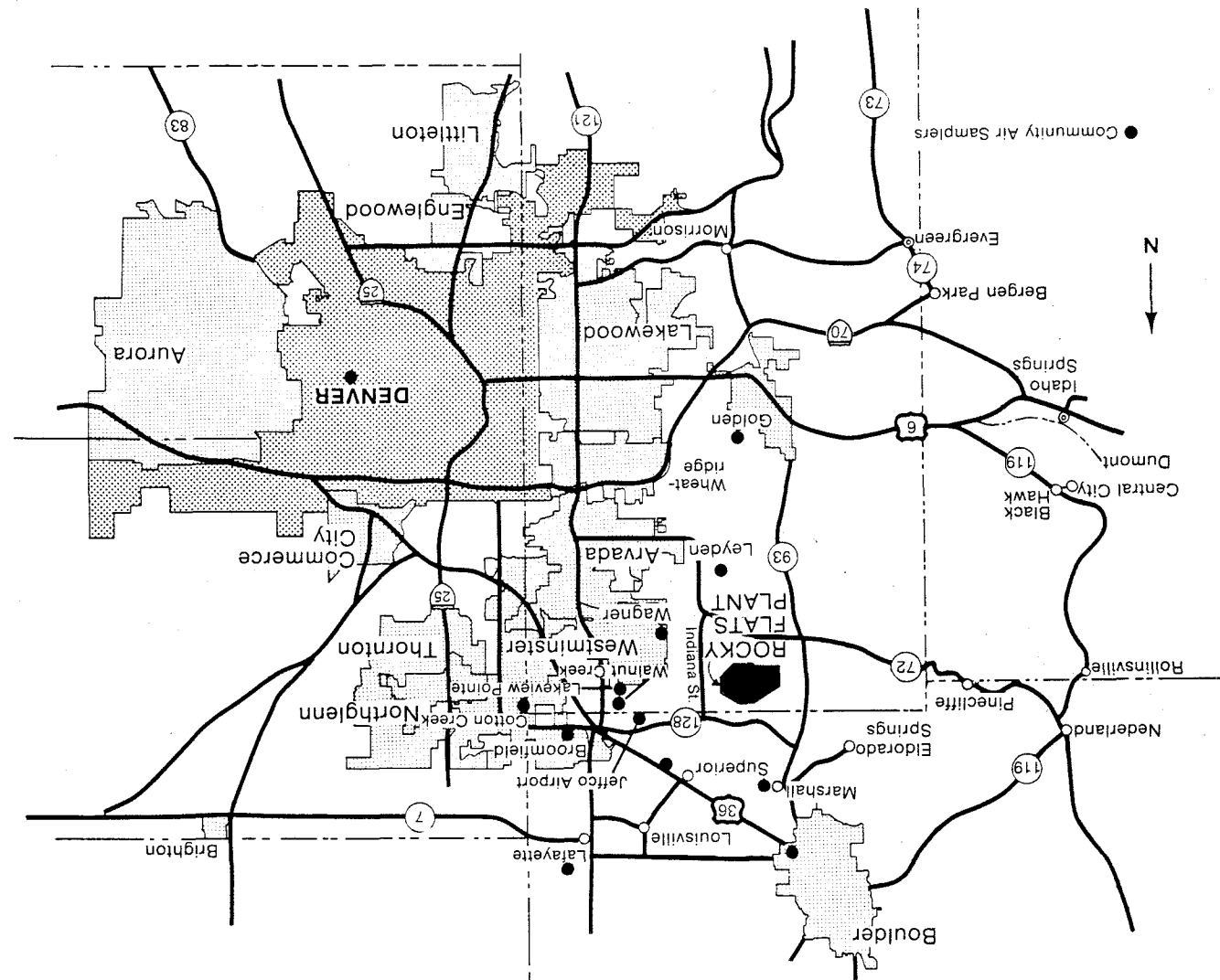


FIGURE 2. Area Map of Rocky Flats Plant and Surrounding Communities

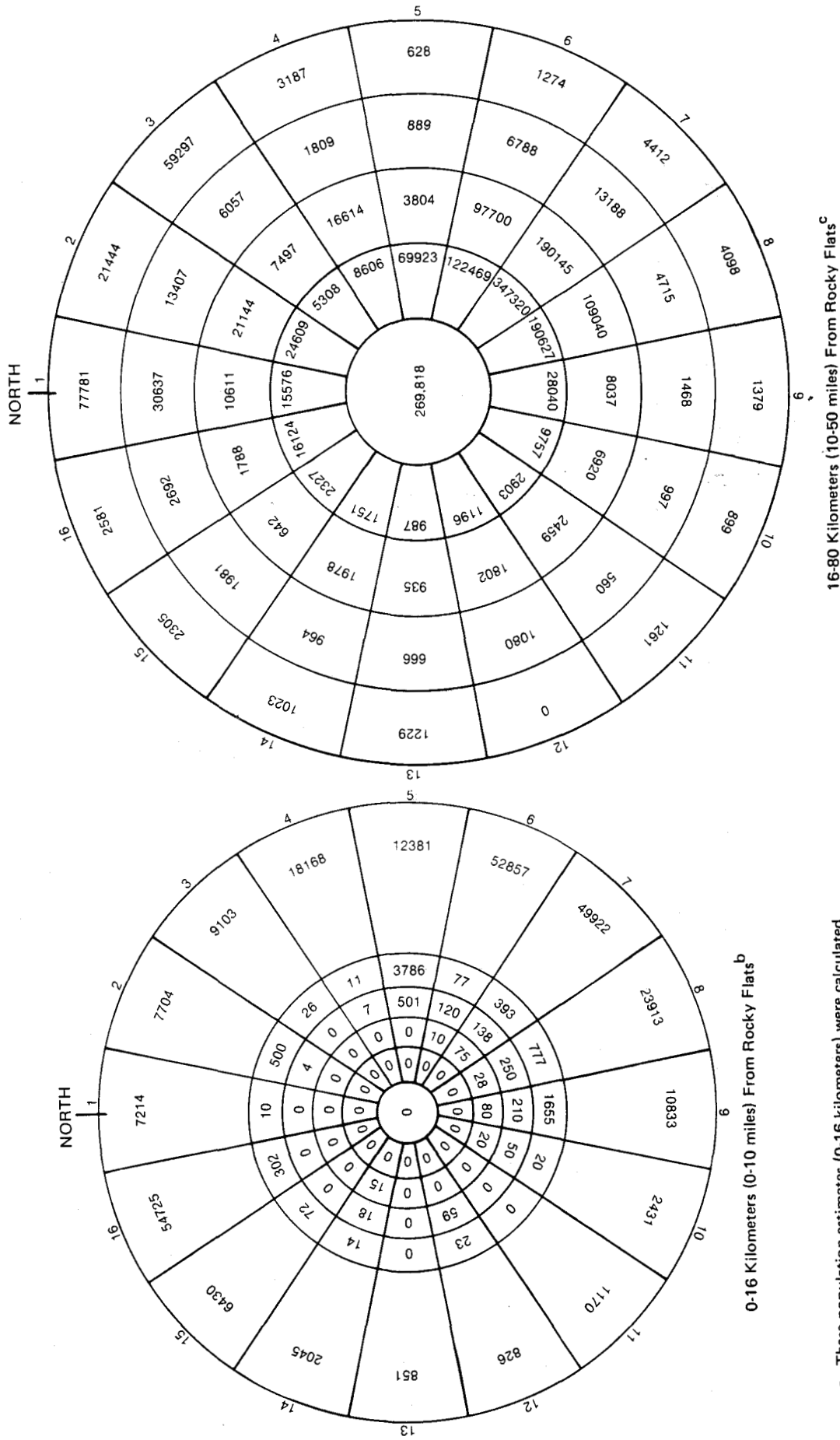
plant to ensure that the filtration efficiency is not less than the standard. Airborne radioactivity released to the environment from process operations is kept to a minimum and is well within plant health and safety guidelines.

As shown in Figure 4, surface water runoff from the plant is from west to east. Runoff is carried from the plant by three major drainage basins that are tributaries to Walnut Creek on the north and to Woman Creek on the south. The south fork of Walnut Creek receives most of the stormwater runoff from areas surrounding plant buildings.

between April and September. Most of the remaining precipitation is in the form of snow.

Air from production and research facilities is continuously discharged to the atmosphere by 43 ventilation exhaust systems. Prior to atmospheric discharge, the exhaust air passes through particulate filtration systems. These filtration systems employ High Efficiency Particulate Air (HEPA) filters, that are purchased to equal or exceed the DOE specified filtration efficiency standard of 99.97 percent for 0.3- μ m particles. Prior to installation in the filter plenums, each filter is tested at the

FIGURE 3. Demographic Estimates - 1980^a



- a. These population estimates (0-16 kilometers) were calculated from 1980 Census Tract Data, assuming even population distribution throughout the sector.
- b. Concentric circles represent 1-to-2, 2-to-3, 3-to-4, 4-to-5, and 5-to-10-mile mileage bands.
- c. Concentric circles represent 10-to-20, 20-to-30, 30-to-40, and 40-to-50-mile mileage bands.

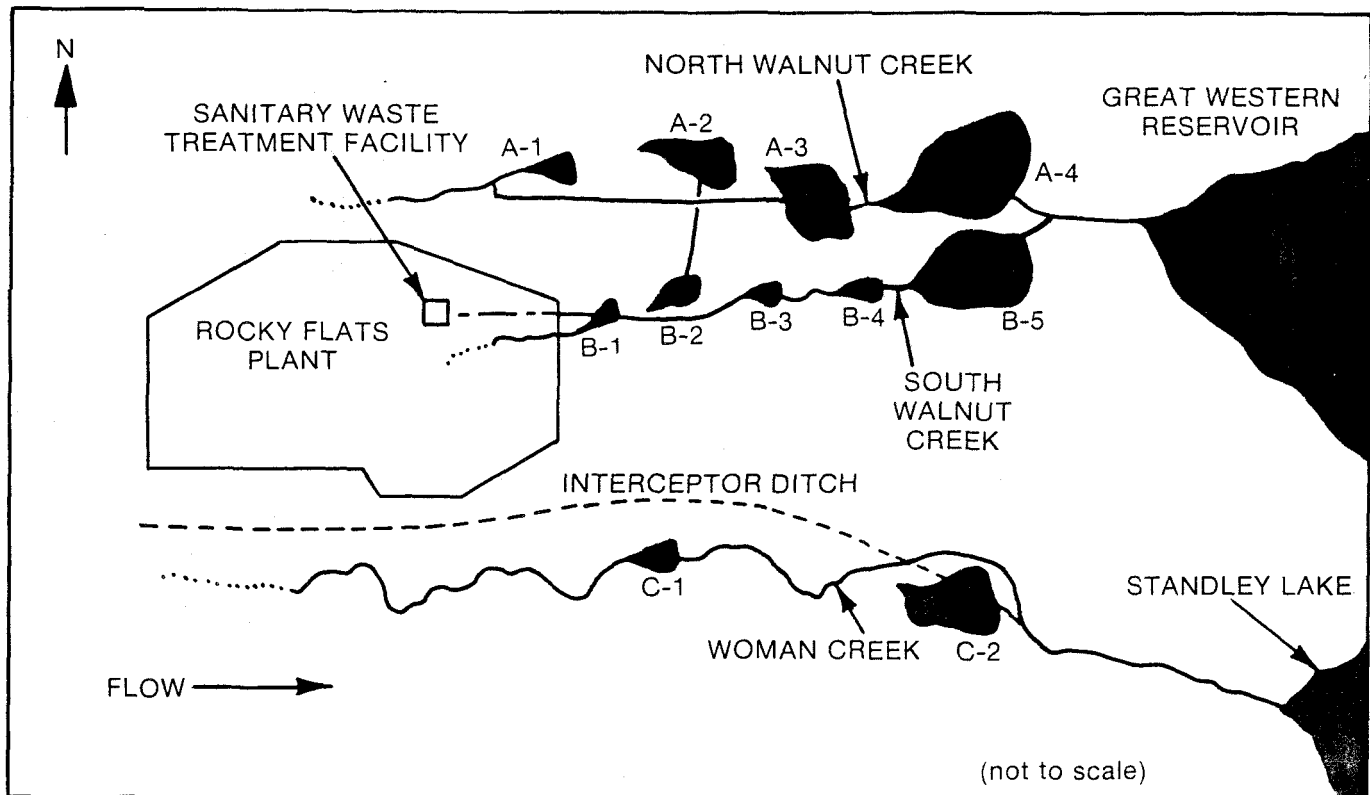


FIGURE 4. Holding Ponds and Liquid Effluent Watercourses

Also shown in Figures 1 and 4 is the confluence of the north and south forks of Walnut Creek which is 1.1 kilometers (0.7 miles) west of the eastern perimeter of the plant. Great Western Reservoir, a water supply for a part of the City of Broomfield, is 1.6 kilometers (1 mile) east of this confluence. Woman Creek flows east from Rocky Flats into Standley Lake, a water supply for the City of Westminster and for portions of the cities of Northglenn and Thornton. Ponds on the north fork of Walnut Creek are designated A-1 through A-4. Ponds on the south fork are designated B-1 through B-5. These ponds receive runoff and/or treated sanitary wastewater. Pond C-1 is located on the Woman Creek watercourse. Pond C-2, located near the Woman Creek watercourse, receives surface runoff water from an interceptor ditch parallel to the south side of the plant production areas.

Certain operations at the Rocky Flats Plant involve or produce liquids, solids, and gases containing radioactive materials. Radioactive materials are handled in accordance with stringent procedures and within multiple containments (physical barriers)

designed to minimize the release of contaminants to the workplace and the environment. Processing activities include the incineration of plutonium-contaminated materials for recovery of the plutonium that they contain. This recovery operation is in accordance with an incineration permit issued to the plant by the Colorado Department of Health. The radioactive waste systems include collection, filtration, liquid processing, and temporary storage facilities for those process wastes known, or suspected, to have been in contact with radioactive materials. The liquid waste process system concentrates liquid wastes containing unrecoverable radioactive materials into solid wastes suitable for shipment, along with other contaminated solid wastes, to a DOE-approved storage facility. Specific details of plant waste processing facilities are described in the Rocky Flats Plant Site Final Environmental Impact Statement.(US80a)

Sanitary waste is processed by the sanitary waste treatment plant, and is isolated from process waste throughout the plant. Conditioning chemicals are added to assist in the destruction of biologically

degradable organic waste. The treatment plant is of the activated sludge type and has three stages of treatment. It has a design capacity of 946,250 liters (250,000 gallons) per day. Present daily flows usually vary between 757,000 and 1,135,500 liters (200,000 and 300,000 gallons) per day. One of two 265,000-liter (70,000 gallon) preaeration holding tanks, located upstream from the sewage plant, serves as a surge basin to smooth out peak flows. A second holding tank provides storage capacity for sanitary wastes should emergency retention be required. Liquid effluents from the sanitary waste treatment plant are released to holding ponds for subsequent use in onsite irrigation or offsite discharge to Walnut Creek, or they may be pumped to a reverse osmosis facility for further treatment. After treatment, product water from the reverse osmosis facility can be recycled for use in plant cooling towers, spray irrigation, or may be released to Walnut Creek. The plant has a zero discharge goal with respect to downstream discharges. Such discharges occur only when storm events prevent effective spray irrigation activities.

Residual solids from the sanitary waste treatment plant are concentrated, dried, packaged, and shipped to a DOE-approved waste facility. Reverse osmosis brine is sent to process waste treatment for evaporation and drying, and the salts are packaged and shipped to a DOE-approved storage facility.

Nonradioactive solid wastes are transferred to an onsite sanitary landfill for disposal. This landfill was designed and constructed in 1974 with an impervious clay seal layer and surface water diversion ditches. Routine materials are checked daily for radioactivity at the landfill site before final burial. The disposal of nonroutine or special non-radioactive waste materials is administratively controlled.

Groundwater and surface water flow in and around the sanitary landfill is controlled by interceptor trenches and by french drains. The trenches divert all upgradient waters around the landfill. The drains collect groundwater from the perimeter of the landfill and divert it into a holding pond. The holding pond collects subsurface drainage from the landfill. Water samples from this holding

pond, the drains, and the three test wells in the vicinity are collected periodically and are analyzed for a series of parameters including radioactivity.

Land use at the Rocky Flats Plant is managed by Rockwell International for the Department of Energy. This includes land utilization planning and environmental and physical control of the land. Since 1977, all major activities conducted on plantsite land require approval by the Rockwell Executive Committee based upon the recommendations of a Land Management Coordinator. The Coordinator evaluates all research projects and other nonroutine activities on plant lands by means of a Land Use Request system. The effects of such activities are evaluated by Environmental Management personnel through field observations and remote sensing techniques.

Personnel in the Environmental Management Group of Rockwell International conduct an extensive environmental control and surveillance program at the plant. The surveillance program is designed to provide assurance that the many safeguards at the plant effectively limit the release of radioactive or toxic materials. The results of this environmental monitoring program indicate that effluent treatment and control processes at the plant were effective during 1986.

The Rocky Flats environs are monitored for penetrating ionizing radiation and for pertinent radioactive, chemical, and biological pollutants. Air, water, soil, and vegetation are sampled on the plantsite and throughout the surrounding region. Several Federal, State, and local governmental agencies independently conduct audits and additional environmental surveys both on and off the plantsite. The Colorado Department of Health samples air, soil, and water at the Rocky Flats site and in surrounding communities. The DOE Environmental Measurements Laboratory (EML) has conducted particulate air sampling at the Rocky Flats Plant and periodically performs special studies, including sediment and soil analyses. Additional special analyses have been performed by Region VIII of the U. S. Environmental Protection Agency (EPA).

Plutonium concentrations in this report represent the alpha radioactivity from plutonium isotopes 239 and 240, which constitute over 97 percent of the alpha radioactivity in plutonium handled at the plant. Reported uranium concentrations are the cumulative alpha activity from uranium-233, -234, and -238. Components containing fully enriched uranium are handled at the Rocky Flats Plant. Depleted uranium metal is fabricated and also is handled as process waste material. Uranium-235 is the major isotope by weight (93 percent) in fully enriched uranium; however, uranium-234 accounts for approximately 97 percent of the alpha activity of fully enriched uranium. In depleted uranium, the combined alpha activity from uranium-234 and -238 accounts for approximately 99 percent of the total alpha activity. The Derived Concentration Guides (DCGs) used in this report for uranium in air and water are those for uranium-233, -234, and -238, which are the most restrictive.*

The information contained in this report is submitted in compliance with DOE Order 5484.1, Chapters III and IV and is a compilation of data provided monthly to the DOE Rocky Flats Area Office, the Radiation Control Division of the Colorado Department of Health, Region VIII of the EPA, the health departments of Boulder and Jefferson Counties, and to interested city officials and citizens from communities near the plant.

II. SITE METEOROLOGY AND CLIMATOLOGY

Wind and temperature data were collected on the plantsite during 1986. Table 1 is the 1986 annual summary of the percent frequency of wind directions (16 compass points) divided into four speed categories. The compass point designations indicate the true bearing when facing against the wind. These frequency values are represented graphically in Figure 5. The wind rose vectors also represent the bearing against the wind (i.e., wind along each vector blows toward the center). The

TABLE 1. Wind Direction Frequency (Percent), by Four Wind-Speed Classes, at the Rocky Flats Plant

(Fifteen-Minute Averages--1986)^a

	Calm	1-3 (m/s) ^b	3-7 (m/s)	7-15 (m/s)	>15 (m/s)	TOTAL
-	7.01	-	-	-	-	7.01
N	-	2.50	2.88	0.33	0.00	5.71
NNE	-	2.78	2.61	0.25	0.00	5.64
NE	-	2.54	1.32	0.09	0.00	3.95
ENE	-	2.06	0.53	0.01	0.00	2.60
E	-	2.33	0.42	0.00	0.00	2.75
ESE	-	2.22	1.00	0.00	0.00	3.22
SE	-	2.71	1.78	0.02	0.00	4.51
SSE	-	2.80	2.50	0.08	0.00	5.38
S	-	2.74	2.59	0.17	0.00	5.50
SSW	-	2.25	2.17	0.21	0.00	4.63
SW	-	2.68	2.49	0.25	0.00	5.42
WSW	-	3.12	4.06	0.88	0.04	8.10
W	-	3.50	2.85	1.97	0.79	9.11
WNW	-	3.64	3.52	3.88	0.54	11.58
NW	-	3.41	3.80	1.09	0.03	8.33
NNW	-	2.79	3.44	0.33	0.00	6.56
TOTALS	7.01	44.07	37.96	9.56	1.40	100.00

a. Data obtained from sensors located approximately 10 m (33 ft) above the ground.

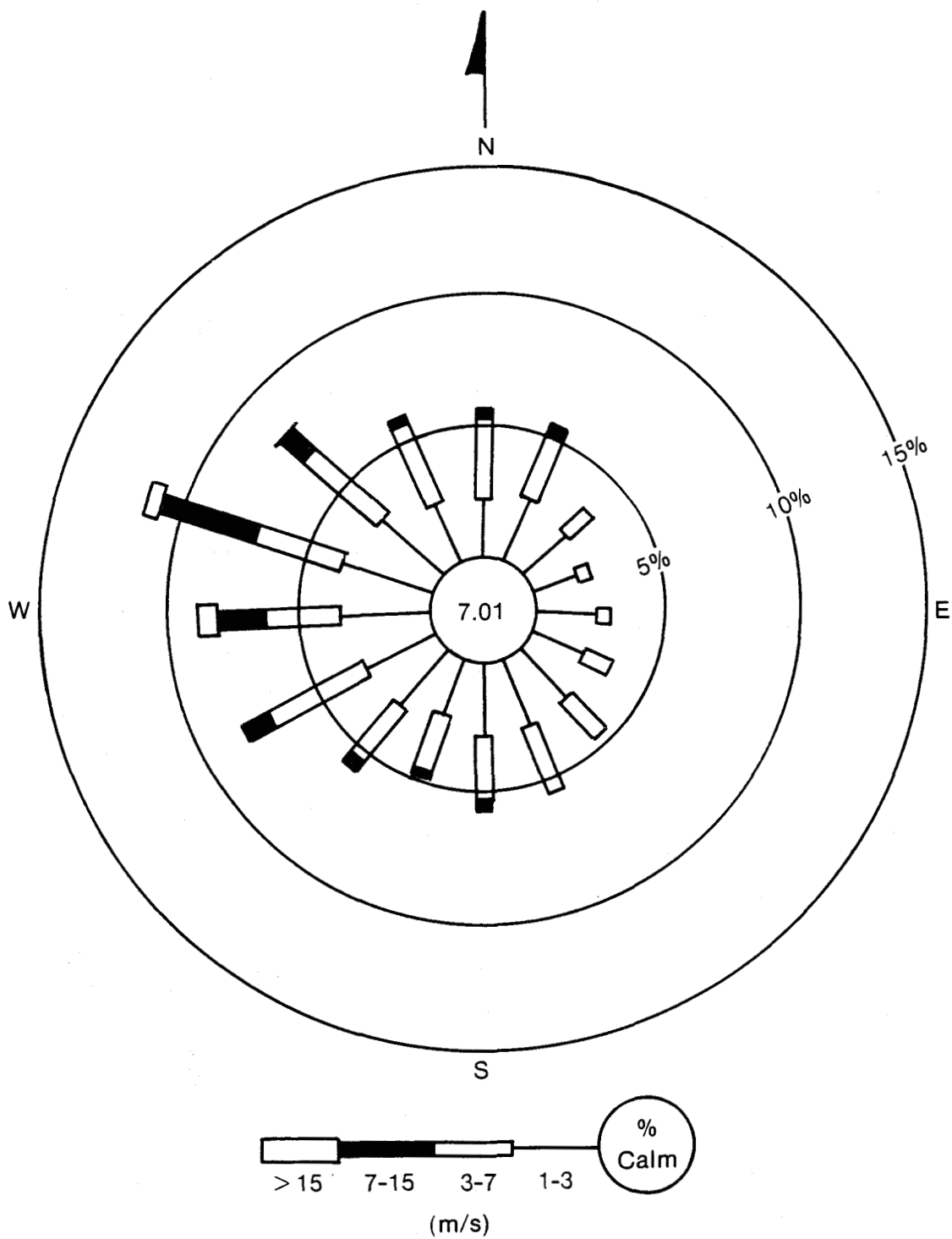
b. For conversion purposes, miles per hour (mph) equals 2.237 multiplied by meters per second (m/s).

predominance of northwesterly winds is typical of Rocky Flats. More calm periods were recorded in 1986 than is usual for the area. The low frequency of winds greater than 7 meters per second (15.6 mph) with easterly components is also normal.

The mean temperature recorded for 1986 was 10.4 °C (50.8 °F). Monthly averaged daily maximum temperatures were below normal for all months in 1986 except August, which recorded a normal monthly averaged daily maximum temperature of 20.8 °C (69.4 °F). Monthly averaged daily minimum temperatures were above normal for all months in 1986. For the purposes

*The Derived Concentration Guides used throughout this report were calculated using the methodology described in Appendix A.

FIGURE 5. 1986 Annual Wind Rose for the Rocky Flats Plant



of comparison, 'normal' was determined using the 24-year monthly averages collected between 1953 and 1976.

Based on the 1953-1976 monthly water-equivalent precipitation averages, mean annual precipitation at Rocky Flats is 38.50 centimeters (15.16 inches).

III. MONITORING SUMMARY

During 1986, the Rocky Flats Plant conducted an environmental monitoring program that included the sampling and analysis of airborne effluents, ambient air, surface and groundwater, and soil. External penetrating gamma radiation exposures were also measured using thermoluminescent dosimeters. The monitoring program consists of collecting samples from onsite, boundary, and offsite locations. Monitoring of water for trace quantities of toxic materials, metals, nitrates, biocides, herbicides, volatile organic compounds (VOCs), and polychlorinated biphenyls (PCBs) also was performed. Specific details of the routine Rocky Flats Environmental Monitoring Program are documented in the "Catalogue of Monitoring Activities at Rocky Flats." (Se86)

Several environmental permits have been issued to the plant by Federal and State agencies. Currently, the following permits are in "Active" status:

National Pollutant Discharge Elimination System Permit CO-0001333; issued by the U. S. Environmental Protection Agency, December 26, 1984.

Building 122 Incinerator Permit C-12, 931; issued by the Colorado Department of Health, March 25, 1982.

Building 771 Incinerator Permit 12JE932 (C-12, 932); issued by the Colorado Department of Health, August 28, 1985.

Building 776 Fluid Bed Incinerator Permit C-13, 022; issued by the Colorado Department of Health, March 25, 1982.

Fugitive Dust Emission Permit 85JE052L for remedial action program, issued by Colorado Department of Health on May 28, 1985.

On July 31, 1986, a Compliance Agreement was entered into by the Environmental Protection Agency (EPA), the Colorado Department of Health (CDH), and the Department of Energy (DOE) for implementation and regulation of the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Compensation and Liability Act (CERCLA) activities for the Rocky Flats Plant. On November 26, 1986, the Rocky Flats Plant submitted a RCRA Part B Permit Application to EPA and CDH. That application currently is undergoing EPA and CDH review.

Particulate and tritium sampling of building exhaust systems was conducted continuously. Overall, 1986 emission data were in the ranges projected in the Plant Environmental Impact Statement(US80a) and presented no significant environmental impact.

Particulate samples are collected from ambient air samplers operated continuously onsite, at the plant perimeter, and in fourteen community locations. Analysis of these samples indicated that the concentrations of airborne plutonium at all locations were far below applicable Derived Concentration Guides (DCGs). (See Appendix A.) At the plant perimeter and at the community locations, the 1986 average plutonium concentrations in ambient air were 0.03 percent of the DOE interim standard DCGs.

During 1986, monitoring of ambient air for total suspended particulates (TSP), ozone (O_3), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), and lead (Pb) was conducted. These six parameters are criteria pollutants regulated by the EPA and the State of Colorado through the Clean Air Act of 1970 that includes the National Ambient Air Quality Standards (NAAQS).(US81b) For TSP, the calculated annual geometric mean was 64 percent of the annual primary geometric mean standard prescribed by the NAAQS. The highest one-hour concentration of O_3 was 151 percent of the EPA primary one-hour standard. This value was consistent with

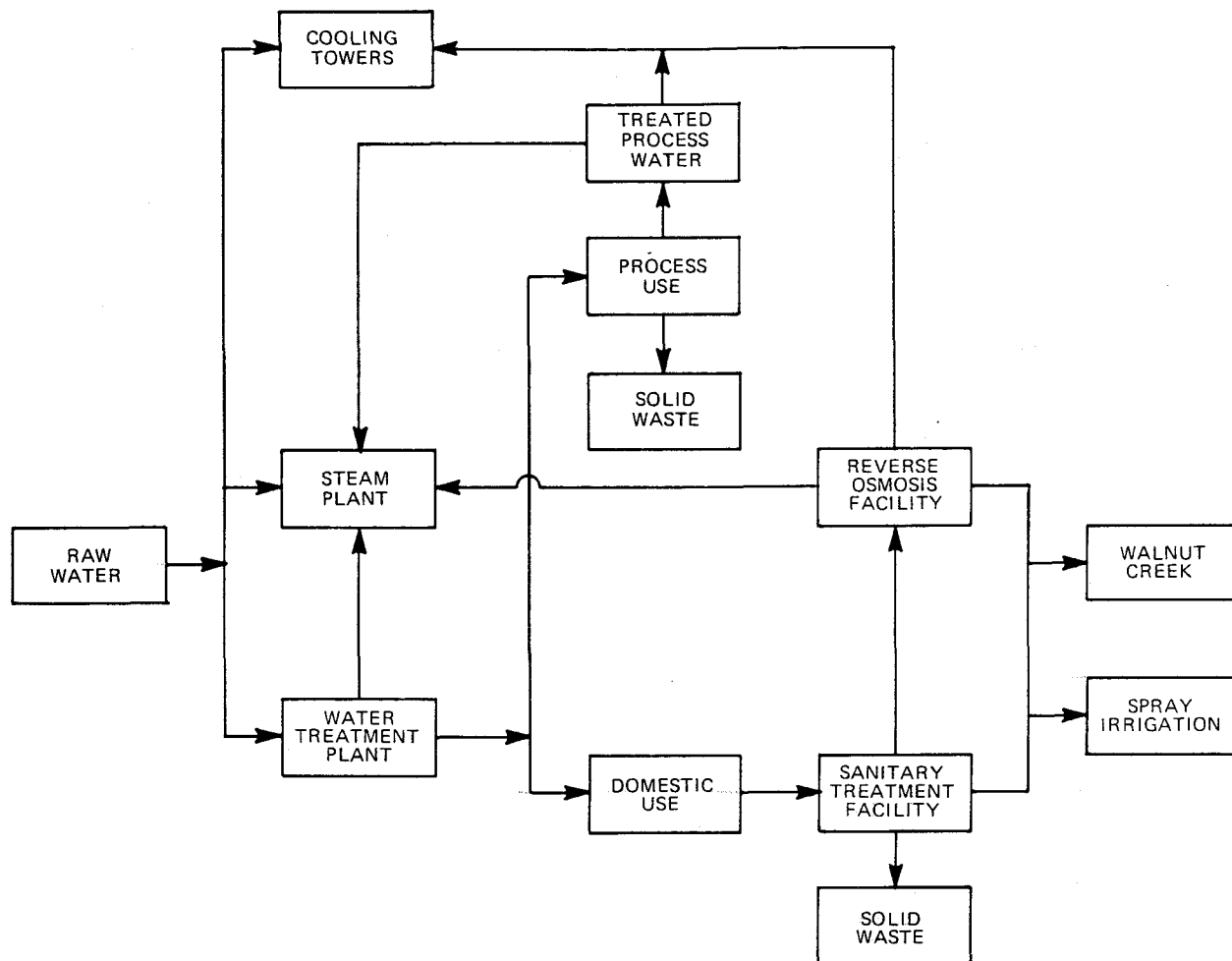


FIGURE 6. Water Use at the Rocky Flats Plant

levels reported in the Denver Metropolitan area at that time. For SO_2 , the annual arithmetic mean was 9 percent of the EPA annual primary mean 3-hour standard. The maximum one-hour primary one-hour standard. The arithmetic mean of the NO_2 concentrations for 1986 was 20 percent of the EPA annual primary mean standard. The quarterly lead concentrations measured during 1986 were less than 6 percent of the EPA quarterly standard.

The majority of the water used during 1986 for plant process operations and sanitary purposes was treated and evaporated and/or reused for cooling tower makeup, steam plant use, or for spray irrigation within the plant boundaries. A schematic diagram of water use is shown in Figure 6.

Surface runoff from precipitation is collected in surface water control ponds. After monitoring, this water is discharged offsite. Those discharges are monitored for compliance with an EPA National Pollutant Discharge Elimination System (NPDES) permit.(US84a) During 1986, the Rocky Flats Plant had no violations of its NPDES permit.

Routine water monitoring is conducted for two downstream reservoirs and for drinking water sources in nine communities. The average radioactivity concentrations for plutonium, uranium, americium, and tritium measured at these locations were found to be 0.4 percent or less of the DCGs for water. (See Appendix A.) The sum of the average concentrations for plutonium and americium in drinking water samples for each

community was 0.1 percent or less of the State of Colorado regulations for alpha-emitting radionuclides (Co77) and the EPA National Interim Primary Drinking Water Regulations. (Fe76) Average concentrations of tritium in community drinking water samples were all within local background range and were 1.5 percent or less of the applicable State of Colorado and EPA drinking water standards. (Co77, Fe76).

As part of the Rocky Flats RCRA/CERCLA Compliance Agreement signed July 31, 1986, extensive hydrologic, geologic and groundwater quality investigations continued throughout the summer of 1986. A new groundwater monitoring network has been installed. The new network consists of 69 new wells and 26 wells installed prior to 1986. Initial analyses from the new network indicate above background concentrations of some constituents within close proximity to past plant disposal sites and plant operations. Those constituents include selected volatile organic compounds, total strontium and some radionuclides. Further sampling will be performed to verify those results. All concentrations of measured radioactive materials are well below the DOE Derived Concentration Guides (DCG).

Biocides and herbicides are used for pest and weed control at the Rocky Flats Plant but were not used in 1986. Water samples collected from Walnut Creek and Woman Creek during 1986 indicated concentrations of these chemicals below the analytical detection limit of 1 part per billion. Polychlorinated biphenyl (PCB) monitoring also showed no concentrations in excess of the analytical detection limit of one part per billion.

Soil samples were collected in 1986 from 40 sites located on radii from Rocky Flats at distances of 1.6 and 3.2 kilometers (1 and 2 miles). The purpose of the program was to determine if there had been any changes in plutonium concentrations in the soil around the plant since a similar set of samples was collected in 1977. This program was reinitiated during 1984. The plutonium concentrations in the 3.2 kilometer samples, which are near the plant boundary, were in the range from 0.02 to 5.3 pCi/g (0.74 to 196 Bq/kg). Plutonium concentrations at a 1.6 kilometer radius ranged from 0.03 to 15 pCi/g (1.1 to 555 Bq/kg). These levels are similar to the soil data reported in 1977.

The 1986 environmental measurement of external penetrating gamma radiation, using thermoluminescent dosimeters (TLDs), showed that the annual dose equivalent onsite, at the plant perimeter, and at community locations, was within the range of regional background.

Potential public radiation dose commitments, which could have resulted from plant operations, were calculated from average radionuclide concentrations measured at the Rocky Flats Plant property boundaries and in surrounding communities. Dose assessment for 1986 was conducted for the property (site) boundary, nearby communities, and to a distance of 80 kilometers (50 miles). At the plant boundary, the maximum 50-year dose commitment to an individual was calculated to be 9.6×10^{-4} rem (9.6×10^{-6} Sv*) effective dose equivalent and 1.5×10^{-2} rem (1.5×10^{-4} Sv) to bone surfaces. By comparison, annual effective dose equivalent from the natural radiation in the Denver area is higher, about 2.6×10^{-1} rem (2.6×10^{-3} Sv). (Na75, Na84, So84) The 50-year dose commitment of 9.6×10^{-4} rem represents less than 1 percent of the DOE interim radiation protection standard of 0.1 rem effective dose equivalent for all pathways. If all the dose were received from the air pathway, the bone surfaces dose of 1.5×10^{-2} rem would represent 20 percent of the air pathway standard for any organ. (Va85)

For community locations, the maximum radiation dose resulted in a 50-year dose commitment of 1.1×10^{-4} rem (1.1×10^{-6} Sv) effective dose equivalent and 2.0×10^{-3} rem (2.0×10^{-5} Sv) to bone surfaces. These values represent 0.1 percent of the DOE interim standard for effective dose equivalent and 3 percent of the standard for any organ from the air pathway only. (Va85) These values include contributions from fallout caused by past atmospheric weapons testing.

The 50-year committed effective dose equivalent to the population living within 80 kilometers (50 miles) of the plant was based on the maximum community dose estimates. For the community, the maximum effective dose equivalent was less than the 1×10^{-3} rem dose equivalent specified by

*1 Sv (Sievert) = 1 J kg^{-1} = 100 rem.

DOE as *de minimis* (inconsequential). (US80b) The dose commitment for all individuals to a distance of 80 kilometers, was therefore, considered to be *de minimis*.

In demonstration of compliance with the EPA air emissions standard in 40 CFR61, Subpart H, the AIRDOS-EPA computer code was used to calculate radiation dose to the public by modeling 1986 air emissions data. The results of this calculation confirm that the maximum radiation dose to a member of the public as a result of exposure to airborne radioactivity from the Rocky Flats Plant in 1986 is less than 1 mrem effective dose equivalent.

IV. MONITORING DATA: COLLECTION, ANALYSES, AND EVALUATION

This section describes Rockwell International's environmental monitoring program for 1986, results of sample analyses, and evaluation of the data with regard to applicable guides and standards. The reader is directed to the appendixes at the end of this report for detailed information concerning applicable guides and standards, quality control, analytical procedures, detection limits, error term propagation, and reporting of minimum detectable concentrations. Appendix E includes a discussion of the methodology used for reporting measurements that were at or below the minimum detectable concentrations (MDC). This appendix also discusses the use of the less-than sign (<) and defines the use of plus or minus (\pm) error terms in the data.

A. Airborne Effluent Monitoring

Production and research facilities at Rocky Flats are equipped with 43 ventilation exhaust systems. Particulates generated by production and research activities are entrained by exhaust air streams. These particulate materials are removed from the air stream in each exhaust system by means of High Efficiency Particulate Air (HEPA) filters. Residual particulates in each of these systems are continuously sampled downstream from the final stage of HEPA filters. For immediate detection of abnormal conditions, ventilation systems that service areas containing plutonium are equipped with Selective Alpha Air Monitors (SAAMs).

These SAAMs are sensitive to selected alpha energy peaks and are set to detect plutonium-239 and -240. These detectors are tested and calibrated routinely to maintain sensitivity. The monitors alarm automatically if out-of-tolerance conditions are experienced. No such conditions occurred during 1986.

Three times each week, continuously collected particulate samples are removed from each exhaust system and are radiometrically analyzed for long-lived alpha emitters. The concentration of long-lived alpha emitters is indicative of the effluent quality and the overall performance of the HEPA filtration systems. If the total long-lived alpha concentration for an effluent sample exceeds the plant action guide value of 0.020×10^{-12} $\mu\text{Ci}/\text{m}^3$ (7.4×10^{-4} Bq/m^3), a followup investigation is conducted to determine the cause and to evaluate the need for corrective action. The action guide is equal to the offsite DCG for plutonium activity in air.

At the end of each month, samples from each ventilation system are composited into a single sample for specific chemical analysis. An aliquot of each of the dissolved composite-samples from the 43 exhaust systems is analyzed for beryllium particulates, using a flameless atomic absorption spectrometry technique. (Bo68) The remainder of the dissolved sample is subjected to chemical separation and alpha spectral analysis to quantify specific alpha-emitting radionuclides. Analyses for uranium isotopes are conducted on the composite samples from each of the 43 exhaust systems. Thirty-five of the ventilation exhaust systems are located in buildings that contain plutonium. Particulate samples from those 35 systems are also analyzed for specific isotopes of plutonium.

Continuous sampling for tritium is conducted in 23 ventilation exhaust systems. Bubbler-type samplers are used to collect samples three times each week at the 23 locations. Tritium concentrations in the sample are measured on a liquid scintillation photospectrometer.

Table 2 presents the quantitative data for radioisotopes in airborne effluents during 1986. Tritium values include contributions from background radioactivity.

TABLE 2. Radioisotopes in Airborne Effluents

Sample Period	Plutonium ^a			Uranium ^b			Tritium		
	Number of Analyses	Total Discharge (μCi)	C_{max}^c ($\times 10^{-12} \mu\text{Ci}/\text{m}\ell$)	Number of Analyses	Total Discharge (μCi)	C_{max}^c ($\times 10^{-12} \mu\text{Ci}/\text{m}\ell$)	Number of Analyses	Total Discharge (Ci)	C_{max}^c ($\times 10^{-12} \mu\text{Ci}/\text{m}\ell$)
January	37	2.30	0.047 \pm 0.0082	45	2.44	0.007 \pm 0.0007	276	0.010	70 \pm 50
February	35	0.62	0.002 \pm 0.0003	43	1.48	0.009 \pm 0.0007	276	0.009	3210 \pm 590
March	35	1.30	0.008 \pm 0.0012	43	1.04	0.004 \pm 0.0003	276	0.008	5200 \pm 640
April	37	0.79	0.019 \pm 0.0042	45	1.87	0.008 \pm 0.0009	291	0.008	1535 \pm 270
May	36	0.63	0.009 \pm 0.0018	46	2.71	0.133 \pm 0.0152	269	0.007	5100 \pm 600
June	37	0.57	0.003 \pm 0.0015	45	2.21	0.006 \pm 0.0006	299	0.004	2055 \pm 310
July	35	1.35	0.004 \pm 0.0008	43	2.62	0.012 \pm 0.0011	297	0.019	3825 \pm 450
August	35	0.71	0.004 \pm 0.0004	44	1.12	0.011 \pm 0.0010	263	0.037	3070 \pm 330
September	35	1.60	0.005 \pm 0.0006	43	1.16	0.007 \pm 0.0008	267	0.017	1460 \pm 230
October	35	2.09	0.008 \pm 0.0018	44	1.87	0.089 \pm 0.0081	319	0.078	36700 \pm 950
November	35	1.64	0.006 \pm 0.0008	43	1.49	0.008 \pm 0.0008	270	0.012	740 \pm 220
December	35	0.73	0.003 \pm 0.0003	44	1.23	0.007 \pm 0.0008	284	0.009	560 \pm 130
Summary	427	14.33	0.047 \pm 0.0082	528	21.24	0.133 \pm 0.0152	3387	0.218	36700 \pm 950

a. Radiochemically determined as plutonium-239, -240.

b. Radiochemically determined as uranium-233, -234, and -238.

c. C_{max} is the maximum measured concentration.

During 1986 the total quantity of plutonium discharged to the atmosphere from 35 ventilation exhaust systems was 14.33 μCi (5.30×10^{-5} Bq).

The maximum plutonium concentration of 4.7×10^{-14} $\mu\text{Ci}/\text{m}\ell$ (1.74×10^{-3} Bq/ m^3) was measured during a 3-day period in January from an exhaust system servicing a plutonium recovery facility. The quantity of plutonium from this discharge was 0.86 μCi (3.18×10^4 Bq). Samples collected prior to, and following this three-day period were within the range typically measured in this exhaust system.

The total discharge of uranium from 43 exhaust systems was 21.24 μCi (7.86×10^5 Bq). The maximum uranium concentration of 1.33×10^{-13} $\mu\text{Ci}/\text{m}\ell$ (4.92×10^{-3} Bq/ m^3) was measured from a depleted uranium production facility during a 2-day period in May. The quantity of depleted uranium from this discharge was 0.143 μCi (5.29×10^3 Bq). The tritium discharged from 23 ventilation systems was 0.218 Ci (8.07×10^9 Bq). The maximum tritium concentration of 3.67×10^{-8} $\mu\text{Ci}/\text{m}\ell$ (1.36×10^3 Bq/ m^3) was observed in a sample from a routine operation in a plutonium

production building during October. The quantity of tritium released to the atmosphere as the result of this operation was 0.032 Ci (1.18×10^9 Bq).

Overall, the 1986 data were in the normal ranges projected in the Plant Environmental Impact Statement, and represent no adverse environmental impact.

Table 3 presents the beryllium airborne effluent data for 1986. The total quantity of beryllium discharged from the ventilation exhaust systems was not significantly above the average background levels associated with the analyses.

B. Radioactive Ambient Air Monitoring

High-volume ambient air samplers are located on the Rocky Flats Plantsite, at the plant perimeter [at distances of approximately 3 to 6 kilometers (2 to 4 miles) from the plant's center], and in surrounding communities. These Rocky Flats-designed air samplers operate continuously at a volume flow rate of approximately 12 ℓ/sec (25 ft^3/min), collecting air particulates on 20- \times 25-cm (8- \times 10-in.) Schleicher and Schuell, Inc., S & S 29 fiberglass media. Manufacturer's test specifica-

TABLE 3. Beryllium in Airborne Effluents

Sample Period	Number of Analyses	Total Discharge ^a (g)	C _{max} (μg/m ³)
January	45	0.0037	0.00035
February	43	-0.0001	0.00005
March	43	-0.0159	0.00002
April	45	0.0295	0.00029
May	46	0.0327	0.00029
June	45	0.0058	0.00008
July	43	0.0095	0.00010
August	44	0.0269	0.00021
September	43	0.0119	0.00025
October	44	0.0059	0.00053
November	43	0.0122	0.00009
December	44	0.0077	0.00009
Summary	528	0.1298 ^b	0.00053

a. The beryllium stationary-source emission-standard is no more than 10 grams of beryllium over a 24-hour period under the provisions of subpart C of 40 CFR 61.32(a). (US78)

b. This value is not significantly different from the background associated with the analyses.

tions rate this filter media to be 99.97% efficient for the relevant particle sizes under conditions typically encountered in routine ambient air sampling. (Sc82)

Airborne particulates in ambient air are sampled continuously at 23 locations within and adjacent to the Rocky Flats exclusion area (Figure 7). The sample filters are collected biweekly and analyzed for total long-lived alpha (TLLα). If the TLLα concentration for an ambient air sample exceeds the plant guide value [10×10^{-15} μCi/ml (3.7 × 10⁻⁴ Bq/m³)], a specific plutonium analysis is performed. During 1986, all TLLα concentrations were less than this guide value.

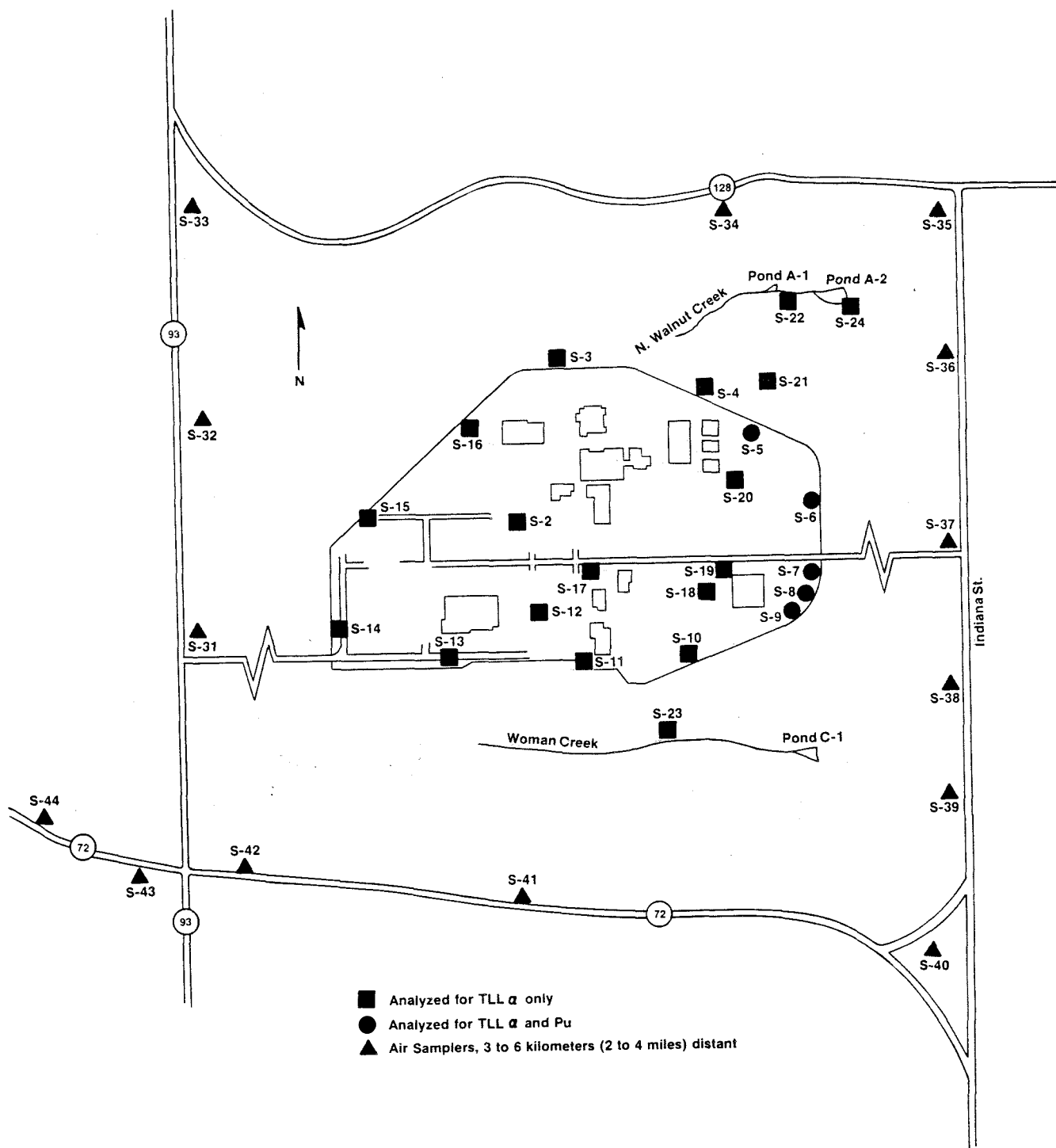
Filters from 5 of the 23 samplers are routinely analyzed biweekly for plutonium. These five onsite samplers have historically shown the highest plutonium concentrations for the sampling network. Table 4 contains the average concentrations of plutonium in ambient air at these stations during 1986. The calculated value for the mean concentration at each location is referred to as the "point estimate." For each plutonium concentration point estimate, a Lower Confidence Limit (LCL) and an Upper Confidence Limit (UCL),

which define a 95 percent confidence interval, have been included in the table. The derivation of the point estimates, the LCL, and the UCL is discussed in Appendix E. The average concentrations of plutonium in ambient air at the five onsite stations during 1986 ranged from 0.088×10^{-15} to 0.458×10^{-15} μCi/ml (3.26 × 10⁻⁶ to 1.70 × 10⁻⁵ Bq/m³). These concentrations are less than 3 percent of the offsite Derived Concentration Guide (DCG) for plutonium in air.

Monitoring for tritium in ambient air is conducted at onsite locations S-4, S-5, and S-16 (Figure 7). Samples are collected and analyzed weekly. The tritium sampler operates continuously at a sampling rate of one-to-two liters of air per minute. Water vapor in the sampled air is collected in a Pyrex tube filled with silica gel. The sampling equipment is contained in an aluminum case that is insulated, weathertight, and lockable. Temperature inside the case is controlled by a small heater and fan that maintain a temperature between 4.44 and 32.2 °C (40 and 90 °F). Table 5 presents the average concentrations of tritium in ambient air at these three onsite stations from February 25, 1986 to January 6, 1987. Prior to February 25, 1986, air flow rates were not recorded and only tritium activity in the condensed water vapor was reported. Annual mean concentration of tritium in ambient air at the three onsite stations during 1986 ranged from 0.17×10^{-12} to 0.37×10^{-12} μCi/ml air (6.29 × 10⁻³ to 1.37 × 10⁻² Bq/m³). These concentrations are less than 0.0002 percent of the offsite DCG for tritium in air.

Samples of airborne particulates are collected on filters by high-volume air samplers at 14 locations along or near the plant perimeter. These perimeter samplers are located between 3 and 6 kilometers (2 and 4 miles) from the plant center. (Figure 7.) The samplers are numbered S-31 through S-44. Samples from each location are collected biweekly, composited by location, and analyzed for a four-week period for plutonium. Table 6 presents the average concentrations of plutonium radioactivity in airborne particulates at Stations S-31 through S-44 during 1986. The mean concentration of plutonium in ambient air at these locations during 1986 was 0.005×10^{-15} μCi/ml (1.85 × 10⁻⁷ Bq/m³). This concentration is 0.03 percent of the offsite DCG for plutonium in air.

FIGURE 7. Location of Onsite and Plant Perimeter Ambient Air Samplers
(Portions of figure are not to scale.)



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TABLE 4. Plutonium-239 and -240 Activity Concentrations in Onsite Ambient Air at Selected Locations^a

Station	Number of Analyses	Volume ($\times 1000 \text{ m}^3$) ^e	Concentration ^b ($\times 10^{-15} \text{ } \mu\text{Ci}/\text{mL}$) ^c									Point ^h Estimate Percent of DCG
			C_{\min}^d			C_{\max}^d			C_{mean}^d			
			LCL ^f	Point Estimate	UCL ^g	LCL	Point Estimate	UCL	LCL	Point Estimate	UCL	
S-5	26	307	0.011	0.015	0.019	0.241	0.278	0.315	0.075	0.088	0.101	0.44
S-6	26	344	0.010	0.014	0.018	0.685	0.757	0.829	0.077	0.088	0.099	0.44
S-7	26	342	0.084	0.096	0.108	0.429	0.496	0.563	0.207	0.236	0.265	1.18
S-8	26	364	0.184	0.207	0.230	0.955	1.087	1.219	0.401	0.458	0.515	2.29
S-9	26	338	0.135	0.152	0.169	0.858	0.946	1.034	0.358	0.405	0.452	2.02

a. These selected air-sampling locations are in the proximity of areas where potential for airborne radioactivity exists (see Figure 7).

b. Two-week samples of station concentrations.

c. To obtain the proper concentration, multiply the numbers in the table by $10^{-15} \text{ } \mu\text{Ci}/\text{mL}$. For example, the average point estimate at S-5 was $0.088 \times 10^{-15} \text{ } \mu\text{Ci}/\text{mL}$.

d. C_{\min} = minimum measured concentration; C_{\max} = maximum measured concentration; C_{mean} = mean measured concentration.

e. To obtain the proper volume, multiply the numbers listed in the table by 1000 m^3 . For example, the volume sampled at S-5 was $307,000 \text{ m}^3$.

f. LCL = lower confidence limit.

g. UCL = upper confidence limit.

h. The interim standard calculated offsite Derived Concentration Guide (DCG) for class W plutonium in air is $20 \times 10^{-15} \text{ } \mu\text{Ci}/\text{mL}$. (See Appendix A.)

TABLE 5. Tritium Activity Concentrations in Onsite Ambient Air Water Vapor^a

Station	Number of Analyses	Air Volume	Condensed Water Vapor (mL)	Concentration ($\times 10^{-12} \text{ } \mu\text{Ci}/\text{mL}$) ^b			C_{mean} ^c Percent of DCG
				C_{\min}	C_{\max}	C_{mean}	
S-4	42	774	1627	-0.24 ± 0.98	0.89 ± 1.19	0.17 ± 0.94	0.00009
S-5	42	572	1484	-0.24 ± 0.70	2.95 ± 1.88	0.37 ± 1.26	0.00019
S-16	42	756	1726	-0.43 ± 1.17	1.17 ± 1.28	0.24 ± 1.02	0.00012

a. Table presents the results of monitoring data from 25 February 1986 through 6 January 1987.

b. To obtain the proper concentration, multiply the numbers in the table by $10^{-12} \text{ } \mu\text{Ci}/\text{mL}$. For example, the average concentration at S-4 was $0.17 \times 10^{-12} \text{ } \mu\text{Ci}/\text{mL}$.

c. The interim standard calculated offsite Derived Concentration Guide (DCG) for tritium in air is $200,000 \times 10^{-12} \text{ } \mu\text{Ci}/\text{mL}$. (See Appendix A.)

Two perimeter samples measured higher than normal plutonium concentrations for one month during 1986. The maximum point estimate recorded at sampler S-37 was $0.231 \times 10^{-15} \text{ } \mu\text{Ci}/\text{mL}$ ($8.55 \times 10^{-6} \text{ Bq}/\text{m}^3$), measured in July. This elevation in airborne plutonium activity was attributed to agricultural plowing activities performed just east of the sampler (Figure 7). The maximum point estimate recorded at sampler S-39

during 1986 was $0.068 \times 10^{-15} \text{ } \mu\text{Ci}/\text{mL}$ ($2.52 \times 10^{-6} \text{ Bq}/\text{m}^3$), measured in September. This elevation in airborne plutonium activity was attributed to road construction (grading) activities in the vicinity of the sampler during that month. Plutonium air concentrations for both locations were well below the DCG at all times and returned to normal levels when plowing and grading activities stopped.

TABLE 6. Plutonium-239 and -240 Activity Concentrations in Perimeter Ambient Air

Station	Number of Analyses	Volume ^b (× 1000 m ³)	Concentration (× 10 ⁻¹⁵ μCi/m ²) ^a									C _{mean} ^c Percent of DCG
			C _{min}			C _{max}			C _{mean}			
			LCL	Point Estimate	UCL	LCL	Point Estimate	UCL	LCL	Point Estimate	UCL	
S-31	12	321	-0.002	0.000	0.002	0.004	0.006	0.008	0.001	0.003	0.004	0.02
S-32	12	310	-0.005	-0.002	0.001	0.010	0.012	0.014	-0.001	0.001	0.003	0.01
S-33	12	399	-0.001	0.000	0.001	0.012	0.015	0.018	0.001	0.002	0.004	0.01
S-34	12	351	-0.001	0.000	0.001	0.005	0.007	0.009	0.001	0.003	0.005	0.02
S-35	12	308	-0.003	-0.001	0.001	0.003	0.006	0.009	-0.001	0.001	0.003	0.01
S-36	12	370	-0.001	0.000	0.001	0.005	0.008	0.011	0.001	0.003	0.004	0.02
S-37	12	363	-0.002	0.001	0.004	0.183	0.231	0.279	0.020	0.027	0.033	0.13
S-38	12	270	-0.001	0.000	0.001	0.003	0.006	0.009	0.001	0.003	0.005	0.02
S-39	11	312	-0.002	0.000	0.002	0.059	0.068	0.077	0.006	0.009	0.011	0.05
S-40	12	353	-0.001	0.000	0.001	0.006	0.008	0.010	0.001	0.003	0.004	0.02
S-41	11	272	-0.003	-0.001	0.001	0.005	0.007	0.009	0.000	0.002	0.004	0.01
S-42	12	313	-0.002	0.000	0.002	0.008	0.010	0.012	0.001	0.003	0.004	0.02
S-43	12	371	-0.002	0.000	0.002	0.002	0.004	0.006	0.000	0.002	0.003	0.01
S-44	11	302	-0.004	-0.002	0.000	0.004	0.006	0.008	-0.001	0.001	0.003	0.01
Summary	165	-	-	-0.002	-	-	0.231	-	-	-	-	-
Average Concentration	-	-	-	-	-	-	-	-	-	0.005	-	0.03

a. To obtain the proper concentration, multiply the numbers listed in the table by $10^{-15} \text{ } \mu\text{Ci}/\text{mL}$.

For example, the mean point estimate at S-31 was $0.003 \times 10^{-15} \text{ } \mu\text{Ci}/\text{mL}$.

b. To obtain the proper volume, multiply the numbers listed in the table by 1000 m^3 .

For example, the volume sampled at S-31 was $321,000 \text{ m}^3$.

c. The interim standard calculated offsite Derived Concentration Guide (DCG) for class W plutonium in air is $20 \times 10^{-15} \text{ } \mu\text{Ci}/\text{mL}$. (See Appendix A.)

Samples of airborne particulates are also collected at 14 locations in or near communities in the vicinity of the Rocky Flats Plant. These locations, shown in Figure 8, are Boulder, Broomfield, Cotton Creek, Denver, Golden, Jeffco Airport, Lafayette, Lakeview Pointe, Leyden, Marshall, Superior, Wagner, Walnut Creek, and Westminster. Sample filters are collected biweekly, composited by location for a four-week period, and analyzed for plutonium radioactivity. Table 7 presents the average concentrations of plutonium in airborne particulates at the community stations during 1986. The mean concentration of plutonium in ambient air at the community stations was $0.003 \times 10^{-15} \text{ } \mu\text{Ci}/\text{mL}$ ($1.11 \times 10^{-7} \text{ Bq}/\text{m}^3$). This value is 0.02 percent of the offsite DCG for plutonium in air.

The Golden community air sampler recorded one anomalous value in 1986. The October point estimate of the plutonium concentration in the ambient air at the Golden sampler was $0.232 \times 10^{-15} \text{ } \mu\text{Ci}/\text{mL}$ ($8.59 \times 10^{-6} \text{ Bq}/\text{m}^3$). Investigation revealed no conclusive explanation for this value but laboratory cross-contamination of the sample during preparation for analysis is suspected. Since this source of error cannot be proven, the value has been included in Table 7.

C. Nonradioactive Ambient Air Monitoring

During 1986, monitoring of ambient air included the following: total suspended particulates (TSP), ozone, sulfur dioxide, carbon monoxide, nitrogen

FIGURE 8. Location of Community Ambient Air Samplers

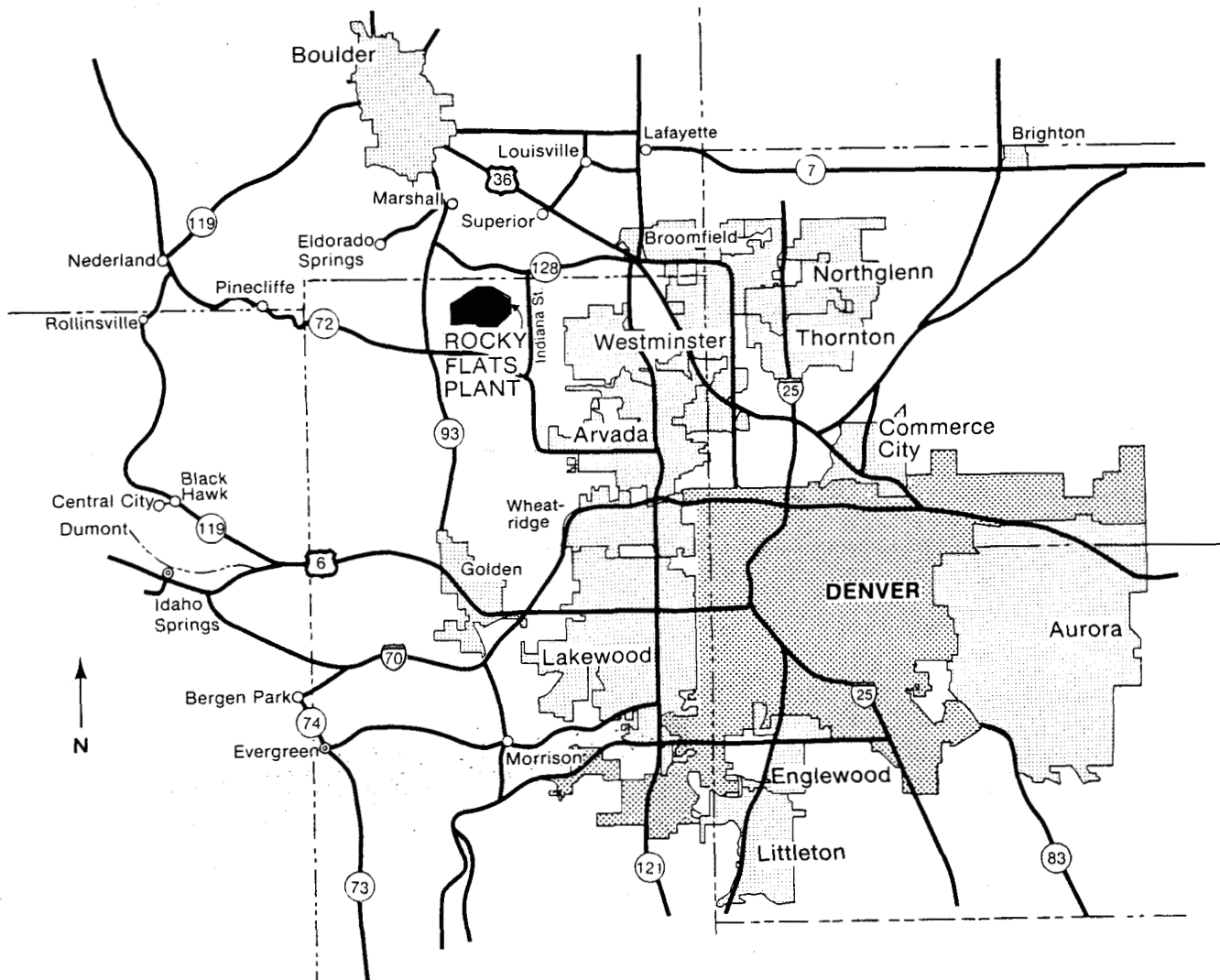


TABLE 7. Plutonium-239 and -240 Activity Concentrations in Community Ambient Air

Station	Number of Analyses	Volume ^b (× 1000 m ³)	Concentration (× 10 ⁻¹⁵ μCi/m ²) ^a									Percent ^c of DCG
			C _{min}			C _{max}			C _{mean}			
			LCL	Point Estimate	UCL	LCL	Point Estimate	UCL	LCL	Point Estimate	UCL	
Marshall	12	288	-0.003	-0.001	0.001	0.008	0.011	0.014	0.001	0.003	0.005	0.02
Jeffco Airport	11	269	-0.002	0.000	0.002	0.004	0.007	0.010	0.001	0.003	0.005	0.02
Superior	12	304	-0.003	-0.001	0.001	0.005	0.008	0.011	-0.001	0.001	0.003	0.01
Boulder	12	355	-0.002	0.000	0.002	0.002	0.003	0.004	-0.001	0.001	0.002	0.01
Lafayette	12	365	-0.002	0.000	0.002	0.004	0.006	0.008	0.001	0.002	0.004	0.01
Broomfield	11	296	-0.002	0.000	0.002	0.003	0.005	0.008	0.000	0.002	0.003	0.01
Walnut Creek	12	358	-0.002	0.000	0.002	0.006	0.008	0.010	0.002	0.003	0.005	0.02
Wagner	12	310	-0.002	0.000	0.002	0.002	0.004	0.006	0.001	0.002	0.004	0.01
Leyden	12	382	-0.001	0.000	0.001	0.006	0.008	0.010	0.000	0.002	0.003	0.01
Westminster	12	290	-0.003	0.000	0.003	0.008	0.010	0.012	0.002	0.004	0.006	0.02
Denver	12	353	-0.003	-0.001	0.001	0.001	0.002	0.003	-0.001	0.000	0.002	0.00
Golden	12	341	-0.002	-0.001	0.000	0.203	0.232	0.261	0.016	0.020	0.024	0.10
Lakeview Pointe	11	319	-0.002	0.000	0.002	0.004	0.007	0.010	0.001	0.002	0.004	0.01
Cotton Creek	11	318	-0.004	-0.001	0.002	0.001	0.002	0.004	-0.001	0.000	0.002	0.00
Summary	164	—	—	-0.001	—	—	0.232	—	—	—	—	—
Mean Concentration	—	—	—	—	—	—	—	—	—	0.003	—	0.02

a. To obtain the proper concentration, multiply the numbers listed in the table by $10^{-15} \text{ } \mu\text{Ci}/\text{m}^3$.

For example, the mean point estimate at Marshall was $0.003 \times 10^{-15} \text{ } \mu\text{Ci}/\text{m}^3$.

b. To obtain the proper volume, multiply the numbers listed in the table by 1000 m^3 .

For example, the volume sampled at Marshall was $288,000 \text{ m}^3$.

c. The interim standard calculated offsite Derived Concentration Guide (DCG) for class W plutonium in air is $20 \times 10^{-15} \text{ } \mu\text{Ci}/\text{m}^3$. (See Appendix A.)

dioxide, and lead. This monitoring utilized instrumentation in a self-contained van equipped for Mobile Ambient Air Monitoring (MAAM) for half the year, then the equipment was transferred into a new monitoring shelter. These six parameters are criteria pollutants regulated by the EPA and the State of Colorado through the Clean Air Act Amendments of 1970 and 1977 which include the National Ambient Air Quality Standards (NAAQS) and Colorado Air Quality Control Commission Ambient Air Standards. Table 8 identifies the detection methods and operating ranges of the monitoring analyzers with corresponding compliance standards. During 1986, the van and new shelter remained stationary at a location near the east entrance to the plant. This is an open area near a traffic zone and is generally downwind from plant buildings. Ambient air data were collected over the entire year with some

limited loss of data experienced during the transfer of monitoring instruments into the new shelter. Proposed Environmental Protection Agency (EPA) regulatory requirements may require selected sampling of particulates in the inhalable and respirable particle size range and total suspended particulate (TSP) sampling may be required as well for tracking 24-hour secondary standards. (US84b) In anticipation of these requirements, the Environmental Management (EM) section of the Rocky Flats Plant co-located a Wedding PM-10 type particulate sampler with its TSP sampler in 1986. The Wedding PM-10 sampler is designed to meet the EPA proposed standard at a flow rate of 40 cubic feet per minute. Co-sampling with the PM-10 sampler and the TSP sampler was begun in 1986. Some limited test data were collected in January-February 1986. These data are not reported, since their population is insufficient

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TABLE 8. Ambient Air Monitoring Detection Methods and National Ambient Air Quality Standards (NAAQS) for Total Suspended Particulates, Ozone, Sulfur Dioxide, Carbon Monoxide, Nitrogen Dioxide, and Lead

Parameter	Detection Methods and Analyzer Ranges	NAAQS Averaging Time	Concentration
Total Suspended Particulates (TSP)	Reference Method (Hi Volume) 24-Hour sampling (6 th-day scheduling)	Annual Geometric Mean:	
		Primary ^a	75 $\mu\text{g}/\text{m}^3$
		Secondary ^b	60 $\mu\text{g}/\text{m}^3$
		24-Hour	
Ozone (O_3)	ThermoElectron Model 49 Ultraviolet Photometry 0-0.5 ppm	Primary ^{a,c}	260 $\mu\text{g}/\text{m}^3$
		Secondary ^{b,c}	150 $\mu\text{g}/\text{m}^3$
Sulfur Dioxide (SO_2)	ThermoElectron Model 43 Pulsed Fluorescence 0-0.5 ppm	1-Hour Primary ^{a,d}	0.12 ppm
Carbon Monoxide (CO)	ThermoElectron Model 48 Gas Filter Correlation (infrared) 0-50 ppm	Annual Arithmetic Mean:	
		Primary ^a	0.030 ppm
		1-Hour Primary ^{a,c}	35 ppm
Nitrogen Dioxide (NO_2)	Monitor Labs Model 8840 Chemiluminescent 0-0.5 ppm	8-Hour Primary ^{a,c}	9 ppm
		Annual Arithmetic Mean: Primary ^a	0.05 ppm
Lead	Reference Method (Hi Volume) 24-Hour Sampling (Atomic Absorption Analysis)	Calendar Quarter Primary ^a	1.5 $\mu\text{g}/\text{m}^3$

a. Primary NAAQS are intended to protect public health.

b. Secondary NAAQS are intended to protect public welfare.

c. Not to be exceeded more than once per year.

d. Statistically estimated number of days with concentrations in excess of the standard is not to be more than 1.0 per year.

for proper analysis or comparison. The new monitoring shelter is being wired to allow continuous operation of both types of samplers. Future sampling for particulates will include both total suspended particulates and particulates in the inhalable/ respirable size range.

Measurement of TSP and lead were conducted using the EPA reference high-volume air sampling method. The primary ambient air particulate sampler and a co-located duplicate sampler were operated on the EPA's sampling schedule of once every sixth day. Particulate data are shown in Table 9. The highest TSP value recorded (a 24-hour sample) was 156 $\mu\text{g}/\text{m}^3$, which is 60 percent of the 24-hour primary standard of 260 $\mu\text{g}/\text{m}^3$. The annual geometric mean value for 1986 was 48 $\mu\text{g}/\text{m}^3$, which was 64 percent of the NAAQS

primary annual geometric mean standard of 75 $\mu\text{g}/\text{m}^3$.

The quarterly average lead concentrations for 1986 were below minimum detectable levels for the first two quarters, 0.043 $\mu\text{g}/\text{m}^3$ for the third quarter, and 0.085 for the last quarter. These values are less than 6 percent of the primary standard of 1.5 $\mu\text{g}/\text{m}^3$.

Ambient ozone data were collected using an ultraviolet (U.V.) photometric type analyzer. During 1986, a total of 7,857 1-hour ozone samples were collected. The maximum 1-hour value was 0.181 ppm, which is 151 percent of the primary one-hour standard of 0.120 ppm. The second highest 1-hour ozone value, which occurred during the same afternoon in July was 0.172 ppm.

TABLE 9. Onsite Ambient Air Quality Data

(Nonradioactive Parameters)

1986

<u>Total Suspended Particulates ($\mu\text{g}/\text{m}^3$)</u>				
Total Number of Samples - "A" ^a				54
Total Number of Samples - "B" ^b				40
Geometric Mean, Sampler "A"				47.7
Geometric Mean, Sampler "B"				47.7
Standard Deviation, Sampler "A"				25.3
Standard Deviation, Sampler "B"				23.8
Observed 24-Hour Maximum, "A"				156.4
Observed 24-Hour Maximum, "B"				145.5
Second Highest Maximum, "A"				92.6
Second Highest Maximum, "B"				-
Lowest Observed Value, "A"				7.40
Lowest Observed Value, "B"				11.60
<u>Ozone (ppm)</u>				
Number of Observations, Hourly ^c				7,857
Arithmetic Mean, Annual				0.037
Maximum 1-Hour Concentration				0.181
Second Highest 1-Hour Concentration				0.172
Minimum Observation, Hourly				0.001
<u>Carbon Monoxide (ppm)</u>				
Number of Observations, Hourly ^c				7,767
Arithmetic Mean, Annual				0.49
Maximum 1-Hour Concentration				9.70
Second Highest 1-Hour Concentration				7.10
Maximum 8-Hour Concentration				2.26
Minimum Hourly Observation				0.05
<u>Nitrogen Dioxide (ppm)</u>				
Number of Observations, Hourly ^c				6,956
Arithmetic Mean				0.010
Maximum 1-Hour Concentration				0.089
Minimum Hourly Observation				0.001
<u>Sulfur Dioxide (ppm)</u>				
Number of Observations, Hourly ^c				6,352
Arithmetic Mean, Annual				0.005
3-Hour Average, Highest				0.046
24-Hour Average, Highest				0.033
Maximum 1-Hour Concentration				0.048
<u>Airborne Lead ($\mu\text{g}/\text{m}^3$)</u>				
	<u>Jan-Mar</u>	<u>Apr-June</u>	<u>Jul-Sep</u>	<u>Oct-Dec</u>
Average of six samples taken quarterly	<0.1	<0.1	0.043	0.085

a. Primary ambient air particulate sampler.

b. Co-located duplicate sampler.

c. Continuous millivolt analyzer output is composited and converted to engineering units for comparison to NAAQS (see Table 8).

These values are consistent with levels measured in the general Denver metropolitan area during high pollution episodes.

Sulfur dioxide sampling was conducted using a continuously operating pulsed fluorescence type analyzer calibrated by use of a certified cylinder gas and a dynamic gas dilution calibration system. The cylinder gases, as well as the mass flowmeters, have traceability to primary standards set by the National Bureau of Standards. The maximum 1-hour SO_2 value recorded at the plant was 0.048 ppm and the maximum observed 3-hour average value was 0.046 ppm, which is 9 percent of the EPA 3-hour standard of 0.500 ppm. The calculated annual arithmetic mean value of 0.005 ppm is 17 percent of the NAAQS annual mean standard of 0.030 ppm. The maximum observed 24-hour average for SO_2 was 0.033 ppm, which is 23 percent of the NAAQS 24-hour standard of 0.140 ppm.

The 7,767 hourly averages of carbon monoxide (CO) data collected during 1986, using a gas filter correlation infrared type analyzer, yielded an annual arithmetic mean of 0.49 ppm, including a maximum 1-hour average value of 9.70 ppm, which is 28 percent of the primary 1-hour standard of 35 ppm. A maximum 8-hour average concentration value of 2.26 ppm was recorded, which is 25 percent of the 8-hour Primary Standard of 9 ppm.

The nitrogen dioxide (NO_2) data contain 6,956 hourly averages of continuous sampling and gave an arithmetic mean of 0.010 ppm, which is 20 percent of the NAAQS primary mean standard value of 0.05 ppm. The maximum 1-hour value noted during this time period was 0.089 ppm.

The data for all parameters were assessed with an accuracy of ± 12 percent based on routine precision and operational span checks, multipoint dynamic calibrations, and established quality assurance procedures.

As part of an ongoing quality assurance program, all of the analyzers were again subjected to an independent annual audit during 1986. Responses of all analyzers were within the range of established EPA guidelines for ambient air monitoring networks ($\pm 15\%$).

D. Waterborne Effluent Monitoring

North Walnut Creek receives surface water runoff from the north side of the plantsite. (See Figure 4.) Holding Pond A-3 on North Walnut Creek is used to impound this surface runoff for analysis prior to discharge. A second control point, holding Pond A-4, is located further downstream.

Ponds A-1 and A-2 are isolated by valves from North Walnut Creek. In the past, these ponds have been used for storage and evaporation of laundry water. This practice was discontinued in 1980. These ponds currently are maintained in a state of readiness for control of possible chemical spills into the North Walnut Creek drainage basin. Disposition of Pond A-1 and A-2 runoff water is through natural evaporation and is enhanced by spraying water through fog nozzles over the surface of the ponds. Excess water that does not evaporate is then recollected by the ponds.

South Walnut Creek receives surface water runoff from the central portion of the plant. This water is diverted through a culvert system to Pond B-4 and then to Pond B-5 where the water is impounded for analysis prior to controlled offsite discharge.

In the past, treated sanitary wastewater was also routinely discharged to South Walnut Creek. This practice was discontinued in 1979. Between 1981 and 1986, some treated sanitary wastewater has been recycled through the plant Reverse Osmosis (RO) Facility for further treatment and reused in plant cooling towers. Excess water that could not be recycled was discharged directly to Pond B-3 or pumped into the RO holding ponds and spray-irrigated onto Rocky Flats buffer zone areas. Ponds B-1 and B-2, also located in the central drainage, are reserved as backup control ponds. These ponds can be used to retain chemical spills, surface water runoff, or treated sanitary wastewater.

Surface runoff water from the south side of the plant is collected in an interceptor ditch and flows to surface water control Pond C-2, where the water is impounded and analyzed before discharge to offsite. Woman Creek, also in the south drainage, is isolated from this diversion system. Pond C-1 is used as the monitoring point for Woman Creek.

Discharges from the Rocky Flats Plant are monitored for compliance with appropriate

Colorado Department of Health Standards and EPA National Pollutant Discharge Elimination System (NPDES) permit limitations.(US84a) Annual average concentrations of chemical and biological constituents of liquid effluent samples collected from Ponds A-3, A-4, B-3, B-5, and C-2 during 1986 are presented in Table 10. The data are indicative of overall water quality for these ponds.

During 1984, the plant NPDES permit expired and was replaced by a renewed NPDES permit with the same seven discharge locations 001, 002, 003, 004, 005, 006, and 007. The discharge locations are identified in Table 10. The NPDES permit places monitoring and reporting requirements and limitations on daily concentrations and monthly average concentrations for some specific parameters. There were no violations of the NPDES permit during 1986.

Prior to discharge from Ponds A-4, B-5, and C-2, water is sampled and analyzed for gross alpha, gross beta, tritium, gamma activity, pH, nitrate as N, and nonvolatile suspended solids. Water is not released if the plant action level for any parameter is exceeded. In general these action levels are based on EPA and CDH drinking water standards.

During releases from Ponds A-4, B-5, and C-2 in 1986, water was sampled continuously. The samples were analyzed for plutonium, uranium, americium, tritium, pH, nitrate as N, and non-volatile suspended solids. Water is also sampled continuously and collected daily from the outfall of Pond C-1 and collected from the Walnut Creek at Indiana Street sampling station when there is flow. Daily samples are composited into weekly samples for plutonium, uranium, and americium analyses. Once each week, daily samples at Pond C-1 and Walnut Creek at Indiana Street are analyzed for tritium. Concentrations of plutonium, uranium, americium, and tritium in water samples from the outfalls of Ponds A-4, B-5, C-1, C-2, and from Walnut Creek at Indiana Street are presented in Tables 11 and 12. All plutonium, uranium, americium, and tritium concentrations at these locations were 1.6 percent or less of the applicable DOE Derived Concentration Guides (DCGs).

TABLE 10. Annual Average Concentrations of Chemical and Biological Constituents in Liquid Effluents^a

Parameter	Number of Analyses	C _{min}	C _{max}	C _{mean}
Discharge 001 ^b	During 1986, there were no discharges made to offsite waters from Pond B-3.			
Discharge 002 ^b				
pH, SU ^c	12	7.5	8.0	—
Nitrate as N, mg/l	12	0.6	7.1	3.5
Discharge 003 ^b	During 1986, there were no discharges made to offsite waters from the Reverse Osmosis Pilot Plant.			
Discharge 004 ^b	During 1986, there were no discharges made to offsite waters from the Reverse Osmosis Plant.			
Discharge 005 ^b				
pH, SU	16	7.4	8.4	—
Nitrates as N, mg/l	16	<0.2	5.2	<2.5
Nonvolatile Suspended Solids, mg/l	16	0.0	140.	14.
Discharge 006 ^b				
pH, SU	34	7.3	8.3	—
Nitrates as N, mg/l	34	<0.2	2.0	<0.8
Nonvolatile Suspended Solids, mg/l	34	0.0	141.	16.
Discharge 007 ^b				
pH, SU	3	8.0	8.4	—
Nitrates as N, mg/l	3	<0.2	0.3	<0.2
Nonvolatile Suspended Solids, mg/l	3	0.0	3.0	2.7

a. Examples of NPDES Permit limitations are presented in Table A-1.

b. The Environmental Protection Agency NPDES discharge permit defines the discharge locations as follows:

- 001 - Pond B-3
- 002 - Pond A-3
- 003 - Reverse Osmosis Pilot Plant
- 004 - Reverse Osmosis Plant
- 005 - Pond A-4
- 006 - Pond B-5
- 007 - Pond C-2

c. SU - Standard Units

As previously mentioned, surface runoff water from the Rocky Flats Plant passes through Ponds A-4, B-5, and C-2 where the water is sampled and analyzed for radionuclides during the discharge process. During 1986, the total curies measured for plutonium from Ponds A-4, B-5, and C-2 were 3.7×10^{-6} , 3.7×10^{-6} , and 0.00, respectively. The total curies measured for uranium were 6.5×10^{-4} , 13.0×10^{-4} , and 2.8×10^{-4} respectively. The total curies measured for americium were 0.00, 3.7×10^{-6} , and 0.00, respectively. And

finally, the total curies measured for tritium from Ponds A-4, B-5, and C-2 were 3.7×10^{-2} , 1.8×10^{-2} , and 0.34×10^{-2} , respectively.

During 1986, Rocky Flats Plant raw water supply was obtained from Ralston Reservoir and from the South Boulder Diversion Canal. Ralston Reservoir water usually contains more natural uranium radioactivity than the water flowing from the South Boulder Diversion Canal. During the year, uranium analyses were performed monthly on

TABLE 11. Plutonium, Uranium, and Americium Concentrations in Water at the Rocky Flats Plant

Location	Number of Analyses	C _{min}	C _{max}	C _{mean}	Percent of DCG
Plutonium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$) ^a					
Pond A-4	8	-0.01 \pm 0.02	0.08 \pm 0.03	0.02 \pm 0.01	0.007
Pond B-5	13	-0.01 \pm 0.02	0.06 \pm 0.02	0.020 \pm 0.006	0.007
Pond C-1	44	-0.01 \pm 0.02	0.04 \pm 0.01	0.015 \pm 0.002	0.005
Pond C-2	1	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	<0.001
Walnut Creek at Indiana Street	34	-0.01 \pm 0.02	0.05 \pm 0.01	0.013 \pm 0.002	0.004
Uranium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$) ^b					
Pond A-4	8	1.2 \pm 0.2	7.3 \pm 0.7	3.5 \pm 0.2	0.7
Pond B-5	13	2.9 \pm 0.4	13 \pm 2	6.9 \pm 0.3	1.4
Pond C-1	44	0.0 \pm 0.1	4.6 \pm 0.4	1.30 \pm 0.03	0.3
Pond C-2	1	8 \pm 2	8 \pm 2	8 \pm 2	1.6
Walnut Creek at Indiana Street	34	0.0 \pm 0.1	11 \pm 1	5.6 \pm 0.1	1.1
Americium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$) ^c					
Pond A-4	8	-0.03 \pm 0.08	0.02 \pm 0.08	-0.01 \pm 0.02	<0.001
Pond B-5	13	-0.03 \pm 0.07	0.2 \pm 0.1	0.02 \pm 0.02	0.03
Pond C-1	44	-0.02 \pm 0.03	0.10 \pm 0.06	0.004 \pm 0.003	0.007
Pond C-2	1	-0.03 \pm 0.08	-0.03 \pm 0.08	-0.03 \pm 0.08	<0.001
Walnut Creek at Indiana Street	34	-0.01 \pm 0.02	0.04 \pm 0.06	0.007 \pm 0.004	0.1

a. Radiochemical determined as plutonium-239 and -240. The interim standard calculated offsite Derived Concentration Guide (DCG) for plutonium in water is 300×10^{-9} $\mu\text{Ci}/\text{mL}$. (See Appendix A.)

b. Radiochemically determined as uranium-233, -234, and -238. The interim standard calculated offsite Derived Concentration Guide (DCG) for uranium in water is 500×10^{-9} $\mu\text{Ci}/\text{mL}$. (See Appendix A.)

c. Radiochemically determined as americium-241. The interim standard calculated offsite Derived Concentration Guide (DCG) for americium in water is 60×10^{-9} $\mu\text{Ci}/\text{mL}$. (See Appendix A.)

samples of Rocky Flats raw water. The uranium concentrations measured during 1986 are presented in Table 13. Uranium concentrations measured during 1986 in raw water averaged 1.0×10^{-9} $\mu\text{Ci}/\text{mL}$ (0.04 Bq/L) or 0.002 $\mu\text{g}/\text{mL}$.

There were no biocides and herbicides used for pest and weed control on the Rocky Flats plant-site during 1986, but water samples were collected from Walnut Creek and Woman Creek and analyzed for these parameters. Analytical results for the materials, 2,4-D and Bromacil, were consistently less than the detection limit of a 1 part per billion. The recommended concentration limit for these compounds is 100 parts per billion.

Approximately 1265 gallons of waste contaminated with polychlorinated biphenyls (PCBs) and low-

level radioactivity are stored in approved holding facilities at the Rocky Flats Plant. Some operating transformers contain PCBs, and each is identified, properly labeled, and protected according to EPA regulations. Analytical results from downstream waters during 1986 showed no concentrations of PCBs in excess of the analytical detection limit of approximately 1 part per billion.

E. Groundwater Monitoring

Extensive hydrogeologic, geologic and groundwater quality investigations continued during 1986 as part of a comprehensive phased program of site characterization, remedial investigations, feasibility studies and remedial/corrective actions. Installation of 69 new RCRA-quality groundwater monitoring wells has yielded valuable information on the

TABLE 12. Tritium Concentrations in Water at the Rocky Flats Plant

Location	Number of Analyses	Tritium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$) ^a		C_{mean}	Percent of DCG
		C_{min}	C_{max}		
Pond A-4	14	0 \pm 400	800 \pm 400	200 \pm 100	0.01
Pond B-5	33	-500 \pm 400	1000 \pm 600	100 \pm 100	0.005
Pond C-1	41	-700 \pm 600	600 \pm 500	100 \pm 100	0.005
Pond C-2	2	-100 \pm 400	300 \pm 400	100 \pm 300	0.005
Walnut Creek at Indiana Street	32	-300 \pm 400	700 \pm 400	200 \pm 100	0.01

a. The interim standard calculated offsite Derived Concentration Guide (DCG) for tritium in water is $2,000,000 \times 10^{-9}$ $\mu\text{Ci}/\text{mL}$. (See Appendix A.)

TABLE 13. Uranium Concentrations in the Rocky Flats Plant Raw Water Supply

Location	Number of Analyses	Uranium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$) ^a		C_{mean}	Percent of DCG
		C_{min}	C_{max}		
Rocky Flats Raw Water ^b	12	0.3 \pm 0.1	2.4 \pm 0.3	1.00 \pm 0.05	0.2

a. Radiochemically determined as uranium-233, -234, and -238.

The interim standard calculated offsite Derived Concentration Guide (DCG) for uranium in water is 500×10^{-9} $\mu\text{Ci}/\text{mL}$. (See Appendix A.)

b. Source of raw water - Ralston Reservoir and South Boulder Diversion Canal.

hydrogeology, geology and groundwater quality at the plant. A complete report of the 1986 investigations is provided in the Rocky Flats Plant RCRA Part B Permit Application.(Ro86) A summary is provided in this section of the Annual Report.

Geology—Surficial materials consist of the Rocky Flats Alluvium, alluvial deposits in the valleys and colluvium (slope wash). The Rocky Flats Alluvium is topographically the highest and is the oldest of the alluvial deposits in the vicinity of the plant. The Verdos Alluvium, Slocum Alluvium, Terrace Alluvium, and Quaternary Alluvium (most recent channel deposits) are found in the drainages and are primarily reworked Rocky Flats Alluvium with the addition of some bedrock material. The Rocky Flats Alluvium is a poorly sorted Quaternary deposit of sand, gravel and cobbles in a clay matrix. Its thickness varies greatly because it was deposited upon an erosional surface cut into bedrock. The thickest portion occurs on the west side of the plant (up to 100 feet) and is thinnest

to nonexistent on the east edge of the plant (see Figure 9).

Bedrock at Rocky Flats is comprised of two fluvial formations of Cretaceous age, the Arapahoe which is immediately beneath the 384 acre plant-site and the upper Laramie which underlies the west buffer zone. The Arapahoe consists of fluvial claystones with interbedded discontinuous lenticular sandstones and siltstones, which are stratigraphically complex. Weathering has penetrated the bedrock 10-40 feet below the surficial material. The upper Laramie consists of a fluvial sequence of sandstones, siltstones and coal. Both formations, under the plant, dip approximately 5 to 15 degrees eastward toward the Denver Basin.

Hydrogeology—There are two hydraulically connected groundwater flow systems at the Rocky Flats Plant. These occur in the Rocky Flats Alluvium and other surficial materials (including valley fill materials), and in the bedrock, primarily the claystones and sandstones of the Arapahoe Formation.

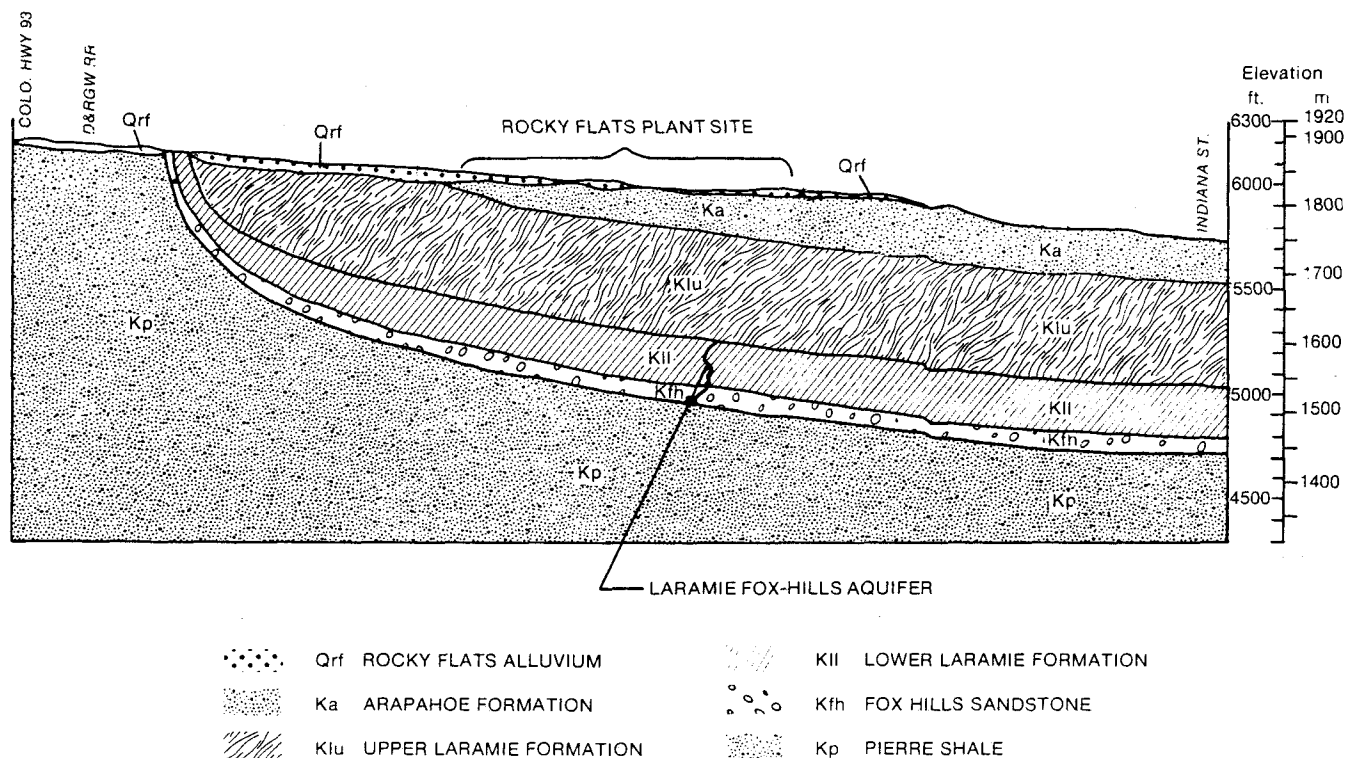


FIGURE 9. Geologic Cross-Section in the Rocky Flats Plant Area

The shallow groundwater flow system occurs in the Rocky Flats Alluvium and other surficial materials under unconfined conditions. This system is recharged by infiltration from incident precipitation, creeks, ponds, surface water diversion canals and spray evaporation/irrigation systems. Monthly water level measurements (potentiometric conditions) show this system to be quite dynamic, with large fluctuations in response to seasonal and other stresses. Potentiometric conditions show that large areas of the plant have little or no water saturation. These unsaturated areas at times may become extensive enough to prohibit any subsurface flow off the plant boundaries.

Flow direction of water in the alluvial system generally follows topography, to the east and toward drainages. In addition, water flow directions are also controlled by the configuration of the bedrock surface beneath the surficial material. Groundwater discharges through evapotranspiration, springflow, baseflow to the drainages, and subsurface flow.

The majority of the groundwater movement in the Arapahoe Formation occurs in the sandstone lenses. Recharge to the sandstone lenses occurs where they are in direct contact with the alluvium (subcrop areas) or by leakage through the weathered claystone. Groundwater flow is easterly to an area of discharge along the South Platte River.

Sampling and Analysis—During 1986, samples were collected from the newly installed wells and from 26 pre-1986 wells (see Figure 10). Many of the pre-86 wells (installed during the 1960-1982 period) were deemed unacceptable monitoring wells due to their construction material and design. Therefore, a new monitoring well network was designed, and plans and specifications for RCRA quality well construction were developed and submitted to both the Environmental Protection Agency (EPA) and the Colorado Department of Health (CDH) for approval as part of a comprehensive hydrogeologic site characterization plan. The plan was approved in August 1986, and 69

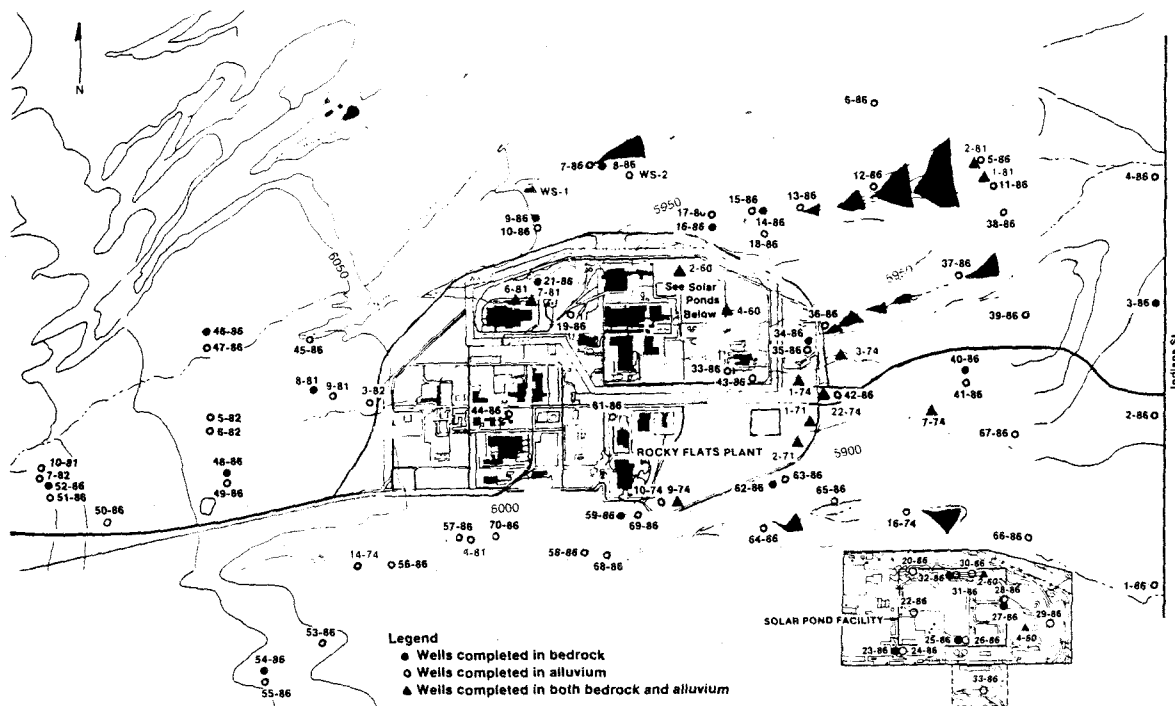


FIGURE 10. Locations of Groundwater Monitoring Wells at Rocky Flats

new monitoring wells were installed over the next four months. Due to the timeframe of installation of new wells, only one set of samples was collected and analyzed in 1986.

Groundwater samples were analyzed for inorganic, organic, radioactive, and other water quality indicator parameters. The specific parameters analyzed are listed in Table 14.

Results of groundwater sampling indicate that some water in both the bedrock and surficial material on plantsite is of poorer quality than upgradient (outside RF) groundwater in the Rocky Flats Alluvium. This degraded water is located in close proximity to past disposal sites and plant operations. Common trace constituents are volatile organic compounds, total strontium and some radionuclides. All radionuclide concentrations are well below the Derived Concentration Guides (DCGs) (see Appendix A) for water discharged to uncontrolled areas, Table 15. Plutonium and americium concentrations in Well 2-71 were the highest levels found on plantsite. Plutonium occurred at $32 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$ and americium occurred at $4.4 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$. The well was dry in November and thus could not be resampled to

verify the reported values. The highest concentrations of plutonium and americium recorded at any well at Rocky Flats in the previous six years (1980-1985) occurred in 1980 and were 0.25×10^{-9} and 0.55×10^{-9} $\mu\text{Ci}/\text{mL}$, respectively. The highest concentrations of tetrachloroethene and trichloroethene in the groundwater were found at Well 1-74. During 1986 tetrachloroethene and trichloroethene were found in concentrations of 120,000 ppb and 7,000 ppb, respectively. This tetrachloroethene value is one order or magnitude higher than that found during previous sampling, indicating an anomaly. Well 1-74 was resampled to verify these values; the analysis for the resampling indicated 24,000 ppb of tetrachloroethene and 2,400 ppb of trichloroethene. Concentration guides for volatile organics and total strontium do not exist. The analytical results can be found in Tables 16 through 18.

Groundwater monitoring will continue on a quarterly basis in 1987. Analytical parameters will be the same as listed in Table 14 except for the deletion of semi-volatiles, and pesticides/PCBs, since they were not detected in the screening program and are not regarded as potential contaminants from plant operations. Further analysis

TABLE 14. Groundwater Monitoring Parameters

<u>Indicators</u>
Temperature
pH
Specific Conductance
<u>Metals</u>
Hazardous Substances List Metals
Cesium
Molybdenum
Strontium
<u>Anions</u>
Bicarbonate
Carbonate
Chloride
Cyanide
Nitrate
Sulfate
<u>Organics</u>
Hazardous Substances List Volatiles
Hazardous Substances List Semi-Volatiles
Hazardous Substances List Pesticides/PCBs
<u>Radionuclides</u>
Gross Alpha
Gross Beta
Uranium-233, -234, -238
Americium-241
Plutonium-239, -240
Tritium

NOTE: Temperature, pH, and specific conductance are measured in the laboratory.

TABLE 15. Summary of Plutonium, Uranium, Americium, and Tritium Concentration Ranges in Groundwater at Rocky Flats Plant

	Radioactivity Concentrations ($\times 10^{-9} \mu\text{Ci}/\text{mL}$) ^a		C_{max} Percent of DCG
	C_{min} ^b	C_{max} ^c	
Plutonium-239, -240	-0.48 ± 0.67	$32 \pm 3^{\text{d}}$	10.6
Americium-241	-0.06 ± 0.08	$4.4 \pm 2.3^{\text{d}}$	7.3
Uranium-233, -234	0.37 ± 0.4	33 ± 1	6.6
Uranium-238	0.00 ± 0.01	33 ± 5	5.5
Tritium	-0.15 ± 0.22	0.69 ± 0.24	3.4×10^{-5}

a. To obtain the proper concentration, multiply the numbers in the table by $10^{-9} \mu\text{Ci}/\text{mL}$. For example, the minimum plutonium-239, -240 concentration is $-0.48 \times 10^{-9} \mu\text{Ci}/\text{mL}$.

b. C_{min} is the minimum measured concentration.

c. C_{max} is the maximum measured concentration.

d. Well was dry in November 1986, when attempt was made to re-sample in order to verify this value.

TABLE 16. Radioactivity Concentrations in Groundwater Monitoring Wells

Station	Gross Alpha ($\times 10^{-9}$ $\mu\text{Ci}/\text{m}\ell$) ^a	Gross Beta ($\times 10^{-9}$ $\mu\text{Ci}/\text{m}\ell$)	Plutonium-239, -240 ($\times 10^{-9}$ $\mu\text{Ci}/\text{m}\ell$)	Americium-241 ($\times 10^{-9}$ $\mu\text{Ci}/\text{m}\ell$)	Uranium-233, -234 ($\times 10^{-9}$ $\mu\text{Ci}/\text{m}\ell$)	Uranium-238 ($\times 10^{-9}$ $\mu\text{Ci}/\text{m}\ell$)	Tritium ($\times 10^{-9}$ $\mu\text{Ci}/\text{m}\ell$)
2-60	22 \pm 51	68 \pm 44	-0.05 \pm 0.06	-0.01 \pm 0.02	4.4 \pm 0.6	3.4 \pm 0.5	670 \pm 0.23
4-60	28 \pm 10	27 \pm 9	0.03 \pm 0.46	0.02 \pm 0.06	30 \pm 1	9.3 \pm 0.7	210 \pm 0.22
1-71	6 \pm 3	6 \pm 3	-0.01 \pm 0.07	0.4 \pm 0.07	3.9 \pm 0.5	2.5 \pm 0.4	250 \pm 0.23
2-71	350 \pm 500	1000 \pm 900	32 \pm 3	4.4 \pm 2.3	30 \pm 5	33 \pm 5	-20 \pm 0.22
6-71	36 \pm 29	2 \pm 2	0.04 \pm 0.08	0.05 \pm 0.05	16 \pm 1	11 \pm 1	1500 \pm 0.3
1-74	9 \pm 5	3 \pm 3	0.03 \pm 0.10	0.04 \pm 0.50	3.2 \pm 0.7	2.7 \pm 0.7	260 \pm 0.23
3-74	13 \pm 7	10 \pm 5	-0.16 \pm 0.31	-0.01 \pm 0.09	-0.04 \pm 0.11	-0.03 \pm 0.08	250 \pm 0.22
9-74	28 \pm 16	28 \pm 11	-0.02 \pm 0.07	0.01 \pm 0.08	11 \pm 2	8.2 \pm 1.4	110 \pm 0.22
10-74	Dry						
14-74	Dry						
16-74	Dry						
22-74	13 \pm 7	12 \pm 4	0.13 \pm 0.16	0.05 \pm 0.06	6.0 \pm 0.6	2.4 \pm 0.4	70 \pm 0.22
1-81	22 \pm 16	32 \pm 12	0.05 \pm 0.32	0.01 \pm 0.03	3.3 \pm 0.4	1.8 \pm 0.3	100 \pm 0.22
2-81	43 \pm 18	27 \pm 11	0.15 \pm 0.12	-0.06 \pm 0.08	1.3 \pm 0.3	1.0 \pm 0.3	-20 \pm 0.21
4-81	Dry						
6-81	13 \pm 6	8 \pm 5	0.02 \pm 0.09	-0.03 \pm 0.06	0.59 \pm 0.20	0.48 \pm 0.18	-40 \pm 0.22
7-81	47 \pm 17	24 \pm 6	-0.06 \pm 0.09	0.01 \pm 0.04	2.1 \pm 0.4	2.0 \pm 0.4	100 \pm 0.21
8-81	5 \pm 4	2 \pm 3	0.16 \pm 0.10	0.00 \pm 0.04	3.2 \pm 0.4	1.7 \pm 0.3	0.20 \pm 0.22
9-81	4 \pm 5	4 \pm 3	-0.03 \pm 0.04	0.04 \pm 0.04	0.57 \pm 0.17	0.25 \pm 0.11	0 \pm 0.22
10-81	22 \pm 7	22 \pm 3	0.03 \pm 0.06	0.03 \pm 0.04	0.96 \pm 0.24	0.59 \pm 0.19	33 \pm 0.23
3-82	10 \pm 7	17 \pm 6	-0.07 \pm 0.10	0.00 \pm 0.04	0.54 \pm 0.29	0.44 \pm 0.27	140 \pm 0.22
5-82	2 \pm 3	3 \pm 2	-0.03 \pm 0.04	0.05 \pm 0.05	-0.01 \pm 0.04	0.00 \pm 0.01	-30 \pm 0.22
6-82	79 \pm 39	110 \pm 30	0.05 \pm 0.17	0.03 \pm 0.07	4.0 \pm 0.6	3.7 \pm 0.6	-10 \pm 0.22
7-82	Dry						
1-86	Dry						
2-86	Dry						
3-86	170 \pm 80	220 \pm 40	0.01 \pm 0.07	0.02 \pm 0.13	7.0 \pm 0.7	5.0 \pm 0.6	160 \pm 0.23
4-86	Dry						
5-86	Dry						
6-86	Dry						
7-86	Dry						
8-86	NA	NA	NA	NA	NA	NA	NA
9-86	NA	NA	NA	NA	NA	NA	NA
10-86	NA	NA	NA	NA	NA	NA	NA
11-86	NA	NA	NA	NA	NA	NA	NA
12-86	82 \pm 28	86 \pm 12	-0.05 \pm 0.06	0.00 \pm 0.03	8.8 \pm 0.8	7.0 \pm 0.7	240 \pm 0.22
13-86	Dry						
14-86	54 \pm 24	36 \pm 12	-0.04 \pm 0.07	0.01 \pm 0.03	7.4 \pm 0.7	2.8 \pm 0.4	-90 \pm 0.22
15-86	200 \pm 80	220 \pm 50	-0.03 \pm 0.04	0.08 \pm 0.21	24 \pm 2	24 \pm 2	280 \pm 0.22
16-86	22 \pm 20	33 \pm 21	-0.48 \pm 0.67	0.01 \pm 0.25	3.0 \pm 1.0	2.1 \pm 0.8	110 \pm 0.23
17-86	160 \pm 80	77 \pm 40	-0.21 \pm 0.26	-0.03 \pm 0.09	33 \pm 1	27 \pm 1	690 \pm 0.24
18-86	NA	NA	NA	NA	NA	NA	NA
19-86	170 \pm 240	470 \pm 130	0.01 \pm 0.08	0.00 \pm 0.13	23 \pm 2	22 \pm 2	140 \pm 0.22
20-86	Dry						
21-86	NA	NA	NA	NA	NA	NA	NA
22-86	300 \pm 160	240 \pm 60	0.95 \pm 0.39	0.12 \pm 0.14	24 \pm 3	21 \pm 3	580 \pm 0.23
23-86	NA	NA	NA	NA	NA	NA	NA
24-86	Dry						
25-86	NA	NA	NA	NA	NA	NA	NA
26-86	NA	NA	NA	NA	NA	NA	NA
27-86	NA	NA	NA	NA	NA	NA	NA
28-86	NA	NA	NA	NA	NA	NA	NA
29-86	Dry						
30-86	NA	NA	NA	NA	NA	NA	NA

a. To obtain proper concentration, multiply the numbers in the table by 10^{-9} $\mu\text{Ci}/\text{m}\ell$.

For example uranium-233, -234 in well 55-86 is 5.4×10^{-9} $\mu\text{Ci}/\text{m}\ell$.

b. NA = Not available.

TABLE 16. Radioactivity Concentrations in Groundwater Monitoring Wells (Continued)

Station	Gross Alpha ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$)	Gross Beta ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$)	Plutonium-239, -240 ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$)	Americium-241 ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$)	Uranium-233, -234 ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$)	Uranium-238 ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$)	Tritium ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$)
31-86	Dry						
32-86	Dry						
33-86	Dry						
34-86	17 \pm 25	35 \pm 18	-0.05 \pm 0.07	0.06 \pm 0.11	2.6 \pm 0.4	2.7 \pm 0.4	-150 \pm 0.22
35-86	25 \pm 19	34 \pm 10	-0.03 \pm 0.07	-0.01 \pm 0.02	13 \pm 1	5.7 \pm 0.6	140 \pm 0.23
36-86	Dry						
37-86	Dry						
38-86	Dry						
39-86	44 \pm 21	39 \pm 13	0.00 \pm 0.09	-0.01 \pm 0.03	3.7 \pm 0.4	3.5 \pm 0.4	180 \pm 0.22
40-86	Dry						
41-86	140 \pm 40	94 \pm 18	0.01 \pm 0.08	-0.03 \pm 0.10	6.6 \pm 0.7	6.5 \pm 0.7	130 \pm 0.22
42-86	130 \pm 70	180 \pm 40	0.50 \pm 0.16	0.07 \pm 0.16	9.8 \pm 1.1	11 \pm 1	210 \pm 0.23
43-86	Dry						
44-86	NA	NA	NA	NA	NA	NA	NA
45-86	200 \pm 80	140 \pm 30	0.13 \pm 0.21	0.03 \pm 0.07	11 \pm 1	10 \pm 1	100 \pm 0.22
46-86	NA	NA	NA	NA	NA	NA	NA
47-86	NA ^b	NA	NA	NA	NA	NA	NA
48-86	NA	NA	NA	NA	NA	NA	NA
49-86	NA	NA	NA	NA	NA	NA	NA
50-86	NA	NA	NA	NA	NA	NA	NA
51-86	NA	NA	NA	NA	NA	NA	NA
52-86	NA	NA	NA	NA	NA	NA	NA
53-86	Dry						
54-86	NA	NA	NA	NA	NA	NA	NA
55-86	170 \pm 70	130 \pm 30	-0.05 \pm 0.07	-0.02 \pm 0.04	5.4 \pm 0.5	6.7 \pm 0.6	200 \pm 0.22
56-86	14 \pm 11	24 \pm 5	0.09 \pm 0.06	0.01 \pm 0.06	1.5 \pm 0.3	1.5 \pm 0.3	60 \pm 0.22
57-86	Dry						
58-86	Dry						
59-86	NA	NA	NA	NA	NA	NA	NA
61-86	NA	NA	NA	NA	NA	NA	NA
62-86	NA	NA	NA	NA	NA	NA	NA
63-86	Dry						
64-86	Dry						
65-86	29 \pm 12	21 \pm 6	0.02 \pm 0.10	0.01 \pm 0.03	7.9 \pm 0.7	6.5 \pm 0.7	70 \pm 0.23
66-86	Dry						
67-86	NA	NA	NA	NA	NA	NA	NA
68-86	20 \pm 11	27 \pm 9	-0.02 \pm 0.08	0.00 \pm 0.03	2.4 \pm 0.4	2.2 \pm 0.4	20 \pm 0.21
69-86	200 \pm 60	130 \pm 30	-0.01 \pm 0.08	0.01 \pm 0.04	14 \pm 1	11 \pm 1	20 \pm 0.21
70-86	210 \pm 70	170 \pm 30	0.07 \pm 0.11	0.04 \pm 0.14	9.3 \pm 1.0	10 \pm 1	-60 \pm 0.22
WS-1	8 \pm 5	10 \pm 3	0.08 \pm 0.16	0.02 \pm 0.04	0.53 \pm 0.20	0.30 \pm 0.15	-40 \pm 0.24
WS-2	Dry						

a. To obtain proper concentration, multiply the numbers in the table by 10^{-9} $\mu\text{Ci}/\text{mL}$. For example uranium-233, -234 in well 55-86 is 5.4×10^{-9} $\mu\text{Ci}/\text{mL}$.

b. NA = Not Available.

TABLE 17. Volatile Organic Concentrations in Groundwater Monitoring Wells

Station	1,1 DCE (µg/ℓ)	1,1 DCA (µg/ℓ)	1,1,2 DCE (µg/ℓ)	CHC13 (µg/ℓ)	1,2 DCA (µg/ℓ)	MEK (µg/ℓ)	1,1,1 TCA (µg/ℓ)	CC14 (µg/ℓ)	TCE (µg/ℓ)	1,1,2 TCA (µg/ℓ)	PCE (µg/ℓ)
2-60	ND ^a	ND	ND	10	ND	ND	ND	ND	ND	ND	ND
4-60	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-71	5	ND	13	180	ND	ND	ND	1,600	350	ND	65
2-71	ND	ND	79	79	ND	ND	ND	ND	4,500	ND	15
6-71	ND	ND	ND	24	ND	ND	ND	14	30	ND	ND
1-74	ND	ND	38	ND	ND	ND	ND	ND	7,000	ND	120,000
									2,400 ^b		25,000 ^b
3-74	ND	ND	ND	ND	ND	ND	ND	280	240	ND	450
9-74	7,200	35	42	5	38	22	14,000		11,000	91	4,800
10-74	Dry										
14-74	Dry										
16-74	Dry										
22-74	ND	ND	ND	ND	ND	ND	ND	23	7	ND	6
1-81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-81	Dry										
6-81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7-81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
8-81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9-81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10-81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3-82	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5-82	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6-82	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7-82	Dry										
1-86	Dry										
2-86	Dry										
3-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-86	Dry										
5-86	Dry										
6-86	Dry										
7-86	Dry										
8-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
12-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13-86	Dry										
14-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
15-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
16-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
17-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
18-86	Dry										
19-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
20-86	Dry										
21-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
22-86	ND	ND	36	147	ND	ND	ND	350	410	ND	ND
23-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
24-86	Dry										
25-86	ND	ND	ND	ND	ND	15	ND	ND	ND	ND	ND
26-86	ND	ND	ND	ND	ND	ND	ND	ND	6	ND	ND
27-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
28-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
29-86	Dry										
30-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
31-86	Dry										
32-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
33-86	Dry										
34-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

a. ND = Not Detected.

b. Values determined by resampling.

c. NA = Not Available.

RFP-ENV-86/MONITORING DATA: COLLECTION, ANALYSES, AND EVALUATION

TABLE 17. Volatile Organic Concentrations in Groundwater Monitoring Wells (Continued)

Station	1,1 DCE ($\mu\text{g}/\ell$)	1,1 DCA ($\mu\text{g}/\ell$)	t,1,2 DCE ($\mu\text{g}/\ell$)	CHC13 ($\mu\text{g}/\ell$)	1,2 DCA ($\mu\text{g}/\ell$)	MEK ($\mu\text{g}/\ell$)	1,1,1 TCA ($\mu\text{g}/\ell$)	CC14 ($\mu\text{g}/\ell$)	TCE ($\mu\text{g}/\ell$)	1,1,2 TCA ($\mu\text{g}/\ell$)	PCE ($\mu\text{g}/\ell$)
35-86	28	54	1,070	ND	ND	ND	17	ND	ND	ND	ND
36-86	Dry										
37-86	Dry										
38-86	Dry										
39-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
40-86	Dry										
41-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
42-86	ND	ND	53	159	ND	ND	ND	1,560	260	ND	320
43-86	Dry										
44-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	17
45-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
46-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
47-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
48-86	NA ^c	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
49-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
50-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
51-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
52-86	NA ^b	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
53-86	Dry										
54-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
55-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
56-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
57-86	Dry										
58-86	Dry										
59-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
61-86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
62-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
63-86	Dry										
64-86	Dry										
65-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
66-86	Dry										
67-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
68-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
69-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
70-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WS-1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WS-2	Dry										

a. ND = Not Detected.

b. Values determined by resampling.

c. NA = Not Available.

Legend

1,1 DCE	1,1-Dichloroethene	1,1 DCA	1,1-Dichloroethane
t,1,2 DCE	trans-1,2-Dichloroethene	CHC13	Chloroform
1,2 DCA	1,2-Dichloroethane	1,2 DCA	1,2-Dichloroethane
MEK	2-Butanone	1,1,1 TCA	1,1,1-Trichloroethane
CC14	Carbon Tetrachloride	TCE	Trichloroethene
1,1,2 TCA	1,1,2-Trichloroethane	PCE	Tetrachloroethene

TABLE 18. Metal Concentrations in Groundwater Monitoring Wells

Station	Al (µg/l)	Sb (µg/l)	As (µg/l)	Ba (µg/l)	Be (µg/l)	Cd (µg/l)	Cs (µg/l)	Cr (µg/l)	Co (µg/l)	Cu (µg/l)	Fe (µg/l)	Pb (µg/l)	Mn (µg/l)	Hg (µg/l)	Mo (µg/l)	Ni (µg/l)	Se (µg/l)	Ag (µg/l)	Sr (µg/l)	Tl (µg/l)	V (µg/l)	Zn (µg/l)
2-60	ND ^a	ND	ND	ND	ND	ND	ND	ND	52	ND	480	ND	410	ND	ND	ND	ND	ND	12,900	290	89	4,330
4-60	ND	ND	ND	ND	ND	ND	ND	ND	120	ND	84	ND	52	1.2	ND	ND	19	14	1,250	ND	ND	250
1-71	ND	ND	ND	ND	ND	ND	ND	ND	170	ND	270	ND	143	ND	ND	ND	15	20	580	ND	ND	ND
2-71	ND	ND	ND	ND	ND	ND	ND	ND	110	ND	54,300	88	800	0.24	192	ND	18	20	570	ND	ND	ND
6-71	ND	ND	ND	ND	10	ND	ND	ND	ND	20	500	ND	30	ND	300	ND	ND	ND	3,750	ND	ND	ND
1-74	ND	ND	ND	ND	9.7	ND	ND	ND	ND	ND	ND	ND	340	ND	ND	ND	ND	ND	830	ND	ND	ND
3-74	ND	ND	ND	ND	9.7	ND	ND	ND	ND	ND	ND	16	ND	ND	ND	ND	ND	ND	360	ND	ND	25
9-74	2,380	ND	ND	ND	ND	ND	ND	ND	140	ND	1,310	ND	84	2.3	ND	ND	21	31	1,960	ND	ND	ND
10-74	Dry																					
14-74	Dry																					
16-74	Dry																					
22-74	ND																					
1-81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	65	ND	190	ND	17	14	1,110	ND	ND	ND
2-81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	220	ND	570	ND	ND	ND	ND	ND	1,080	ND	ND	ND
4-81	Dry																					28
6-81	180	ND	ND	ND	ND	ND	ND	ND	220	ND	590	ND	1,480	0.88	ND	ND	15	20	350	ND	ND	ND
7-81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	520	ND	ND	ND	3.4	ND	235	ND	ND	54
8-81	ND	ND	ND	ND	80	ND	ND	13	ND	30	ND	ND	ND	ND	ND	ND	8.2	ND	250	ND	ND	ND
9-81	ND	ND	ND	ND	ND	ND	ND	7.5	ND	ND	6	ND	0.22	ND	ND	ND	ND	ND	350	19	ND	90
10-81	680	ND	ND	ND	37	ND	360	ND	100	ND	270	ND	ND	0.7	510	77	ND	ND	68	7	850	20
3-82	ND	ND	ND	280	40	ND	ND	16	ND	20	ND	ND	80	ND	ND	ND	17	ND	110	ND	ND	75
5-82	ND	ND	ND	150	ND	ND	ND	ND	ND	ND	ND	ND	30	1.2	ND	ND	ND	180	14	ND	ND	1,580
6-82	ND	ND	ND	290	40	ND	ND	22	ND	ND	180	16	140	ND	ND	60	ND	ND	ND	ND	ND	102
7-82	Dry																					
1-86	Dry																					
2-86	Dry																					
3-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	38	0.24	ND	ND	15	ND	1,580	ND	ND	34
4-86	Dry																					
5-86	Dry																					
6-86	Dry																					
7-86	Dry																					
8-86	380	ND	156	ND	ND	ND	ND	ND	ND	94	ND	16	ND	133	ND	10	ND	ND	1,310	ND	ND	29
9-86	ND	ND	ND	160	ND	ND	ND	ND	ND	ND	ND	25	28	ND	ND	ND	ND	ND	175	ND	ND	ND
10-86	36,600	ND	ND	340	26	ND	ND	10	ND	24	28,200	ND	634	0.56	ND	ND	19	238	ND	ND	57	55
11-86	8,400	ND	ND	170	ND	ND	ND	ND	ND	ND	3,590	ND	128	ND	ND	ND	ND	ND	590	ND	ND	27
12-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	20	ND	190	ND	ND	ND	828	ND	ND	25
13-86	Dry																					
14-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	42	ND	ND	ND	ND	ND	1,370	ND	ND	ND
15-86	ND	ND	ND	120	ND	ND	ND	ND	65	ND	ND	ND	26	ND	ND	ND	ND	ND	1,700	24	ND	ND

a. ND = Not Detected.

b. NA = Not Available.

TABLE 18. Metal Concentrations in Groundwater Monitoring Wells (Continued)

Station	Al (µg/l)	Sb (µg/l)	As (µg/l)	Ba (µg/l)	Be (µg/l)	Cd (µg/l)	Cs (µg/l)	Cr (µg/l)	Co (µg/l)	Cu (µg/l)	Fe (µg/l)	Pb (µg/l)	Mn (µg/l)	Hg (µg/l)	Mo (µg/l)	Ni (µg/l)	Se (µg/l)	Ag (µg/l)	Sr (µg/l)	Tl (µg/l)	V (µg/l)	Zn (µg/l)	
16-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	63	0.30	ND	ND	ND	4.5	ND	1,880	ND	ND	ND
17-86	ND	ND	ND	160	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3,950	120	ND	ND
18-86	NA ^b	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
19-86	ND	ND	ND	170	ND	ND	ND	ND	ND	ND	ND	ND	2,230	ND	ND	ND	ND	ND	ND	1,240	30	ND	ND
20-86	Dry																						
21-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	77	ND	ND	ND	ND	10	324	ND	ND	ND	ND
22-86	ND	62	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15	0.67	ND	ND	7.6	ND	320	ND	ND	ND	ND
23-86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
24-86	Dry																						
25-86	610	ND	ND	ND	ND	ND	ND	ND	25	ND	ND	ND	237	ND	313	965	ND	9	2,850	ND	ND	ND	59
26-86	ND	ND	ND	150	ND	ND	ND	ND	ND	ND	ND	ND	117	0.26	ND	ND	ND	ND	2,130	44	ND	ND	ND
27-86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28-86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29-86	Dry																						
30-86	170	ND	ND	580	ND	ND	ND	ND	ND	ND	478	ND	631	1.1	ND	ND	10	30	21,500	544	ND	ND	23
31-86	Dry																						
32-86	ND	ND	ND	100	ND	ND	ND	ND	ND	ND	ND	12	23	ND	ND	ND	ND	10	580	ND	ND	ND	77
33-86	Dry																						
34-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	82	ND	190	ND	8.3	ND	3,240	39	ND	ND	42
35-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2,100	ND	ND	ND	2.8	ND	959	ND	ND	ND	31
36-86	Dry																						
37-86	Dry																						
38-86	Dry																						
39-86	ND	ND	ND	280	ND	ND	ND	ND	ND	ND	ND	ND	35	ND	ND	ND	ND	ND	523	ND	ND	ND	ND
40-86	Dry																						
41-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	854	ND	ND	ND	ND	ND	420	ND	ND	ND	ND
42-86	ND	ND	ND	150	5	ND	ND	ND	ND	ND	ND	ND	578	ND	ND	ND	ND	ND	308	ND	ND	ND	ND
43-86	Dry																						
44-86	4,300	ND	ND	280	ND	ND	ND	ND	ND	ND	2,840	ND	173	ND	ND	ND	ND	ND	285	ND	ND	ND	57
45-86	480	ND	ND	160	11	ND	ND	ND	ND	ND	252	ND	79	0.21	ND	ND	ND	ND	190	ND	ND	ND	6
46-86	350	ND	ND	144	ND	ND	ND	ND	ND	132	ND	13	ND	ND	ND	ND	9	117	ND	ND	ND	ND	ND
47-86	ND	ND	ND	100	ND	7	ND	ND	ND	ND	ND	ND	86	ND	ND	ND	ND	ND	ND	ND	47	ND	ND
48-86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
49-86	ND	ND	ND	116	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	205	ND	ND	ND	ND
50-86	190	ND	ND	190	ND	ND	ND	ND	ND	ND	181	54	347	ND	ND	ND	ND	ND	164	ND	ND	ND	63
51-86	ND	ND	ND	110	ND	6	ND	27	ND	23	ND	ND	71	ND	ND	29	ND	ND	ND	ND	ND	ND	39
52-86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
53-86	Dry																						
54-86	150	ND	ND	ND	ND	ND	ND	15	ND	ND	110	ND	100	ND	ND	ND	ND	ND	326	ND	ND	ND	ND
55-86	740	58	ND	140	11	ND	ND	ND	ND	ND	537	ND	547	ND	ND	ND	ND	ND	154	ND	ND	ND	7
56-86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	340	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
57-86	Dry																						
58-86	Dry																						

a. ND = Not Detected.

b. NA = Not Available.

TABLE 18. Metal Concentrations in Groundwater Monitoring Wells (Continued)

Station	Al ($\mu\text{g/l}$)	Sb ($\mu\text{g/l}$)	As ($\mu\text{g/l}$)	Ba ($\mu\text{g/l}$)	Be ($\mu\text{g/l}$)	Cd ($\mu\text{g/l}$)	Cs ($\mu\text{g/l}$)	Cr ($\mu\text{g/l}$)	Co ($\mu\text{g/l}$)	Cu ($\mu\text{g/l}$)	Fe ($\mu\text{g/l}$)	Pb ($\mu\text{g/l}$)	Mn ($\mu\text{g/l}$)	Hg ($\mu\text{g/l}$)	Mo ($\mu\text{g/l}$)	Ni ($\mu\text{g/l}$)	Se ($\mu\text{g/l}$)	Ag ($\mu\text{g/l}$)	Sr ($\mu\text{g/l}$)	Tl ($\mu\text{g/l}$)	V ($\mu\text{g/l}$)	Zn ($\mu\text{g/l}$)	
59-86	230	185	ND	100	29	ND	ND	ND	ND	ND	ND	24	107	1.2	ND	ND	ND	ND	1,110	ND	ND	ND	12
61-86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
62-86	4,750	58	ND	130	9	ND	ND	39	ND	ND	2,900	ND	52	0.28	ND	ND	ND	ND	305	ND	ND	ND	23
63-86	Dry																						
64-86	Dry																						
65-86	ND	78	ND	ND	10	ND	ND	ND	ND	ND	103	ND	127	1.9	ND	ND	8.9	ND	630	ND	ND	28	
66-86	Dry																						
67-86	ND	ND	ND	243	ND	ND	ND	ND	ND	ND	ND	ND	161	ND	ND	ND	ND	16	719	ND	ND	30	
68-86	ND	95	ND	100	6	ND	ND	ND	ND	ND	76	ND	1,050	ND	ND	ND	ND	ND	137	ND	ND	ND	
69-86	110	208	ND	160	6	ND	ND	ND	ND	ND	ND	37	58	ND	ND	ND	ND	ND	1,190	16	ND	5	
70-86	ND	ND	ND	ND	7	ND	ND	ND	ND	ND	ND	ND	72	0.50	ND	ND	ND	ND	656	ND	ND	ND	
WS-1	ND	ND	ND	ND	30	ND	ND	ND	ND	ND	ND	ND	70	ND	100	ND	ND	ND	120	ND	ND	78	
WS-2	Dry																						

RFP-ENV-86/MONITORING DATA: COLLECTION, ANALYSES, AND EVALUATION

TABLE 19. Other Inorganic Concentrations in Groundwater Monitoring Wells

Station	Calcium (µg/ℓ)	Magnesium (µg/ℓ)	Potassium (µg/ℓ)	Sodium (µg/ℓ)	Bicarbonate (mg/ℓ)	Carbonate (mg/ℓ)	Chloride (mg/ℓ)	Cyanide (mg/ℓ)	Phosphate (mg/ℓ)	Sulfate (mg/ℓ)	Nitrate (mg/ℓ)
2-60	1,500,000	270,000	72,400	540,000	17	80	730	0.014	1.4	400	5060
4-60	171,000	49,000	3,300	127,000	26	350	40	ND	0.52	91	22.0
1-71	84,000	15,000	1,660	11,200	37	240	17	ND	1.6	22	19.9
2-71	84,000	12,500	2,200	135,000	108	35	320	0.016	ND	97	<5.0
6-71	635,000	6,000	6,000	24,000	50	270	95	ND	1.8	100	2120
1-74	105,000	32,000	3,800	106,000	62	250	23	ND	1.8	37	44.8
3-74	25,500	14,000	920	15,500	18	290	40	ND	1.6	30	25.2
9-74	314,000	51,000	2,100	116,000	18	301	400	ND	3.7	320	91.2
10-74	Dry										
14-74	Dry										
16-74	Dry										
22-74	1,420	22,500	4,100	22,400	ND	250	57	ND	1.9	22	23.6
1-81	210	ND	90	76	75	330	37	ND	2.0	250	<5.0
2-81	84,000	41,000	4,250	117,000	108	430	29	ND	2.3	200	<5.0
4-81	Dry										
6-81	84,000	12,500	1,730	4,500	30	210	10	ND	4.4	ND	7.2
7-81	56,000	42,000	980	12,000	26	210	3.1	ND	1.4	9	<5.0
8-81	73,300	5,780	ND	13,800	4.9	130	8.6	0.005	ND	17	<5.0
9-81	28,200	1,480	5,880	15,900	NA	NA	NA	NA	NA	NA	<5.0
10-81	18,000	6,600	560	11,000	19	21	5.7	0.0016	1.3	ND	<5.0
3-82	22,000	3,680	ND	13,800	10	19	15	ND	1.8	28	74.7
5-82	36,200	4,130	15,500	23,300	56	ND	55	ND	0.92	77	32.4
6-82	8,700	1,200	ND	5,100	15	22	3.3	ND	1.5	20	<5.0
7-82	Dry										
1-86	Dry										
2-86	Dry										
3-86	88,000	32,000	2,630	26,600	13	330	58	ND	2.6	66	5.7
4-86	Dry										
5-86	Dry										
6-86	Dry										
7-86	Dry										
8-86	91,500	ND	41,100	177,000	ND	442	NA	NA	4.0	NA	41.0
9-86	21,100	5,250	3,620	60,700	220	ND	11	ND	1.8	15	<5.0
10-86	22,100	7,880	12,900	12,200	16	66	4.3	ND	4.4	17	<5.0
11-86	77,400	24,500	6,840	112,000	NA	NA	NA	NA	NA	NA	NA
12-86	170,000	264,000	1,920	167,000	33	420	47	ND	2.9	240	9.6
13-86	Dry										
14-86	95,100	29,200	7,920	267,000	13	180	160	ND	1.5	310	<5.0
15-86	324,000	61,500	2,600	88,000	35	410	63	0.040	11	170	243
16-86	142,000	45,500	6,260	297,000	22	450	220	ND	ND	510	<5.0
17-86	193,000	142,000	8,800	322,000	53	320	140	ND	2.1	330	2320
18-86	Dry										
19-86	148,000	45,400	5,500	232,000	NA	NA	NA	NA	NA	NA	<5.0
20-86	Dry										
21-86	44,200	9,960	8,030	37,600	4.4	259	5.2	ND	4.7	56	<5.0
22-86	57,000	9,180	4,040	99,700	23	340	37	ND	3	75	22.6
24-86	Dry										
25-86	224,000	80,500	35,000	33,800	NA	NA	NA	NA	NA	NA	NA
26-86	97,000	106,000	3,300	338,000	41	730	77	NR ^c	ND	500	300
27-86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28-86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29-86	Dry										
30-86	193,000	165,000	38,600	1,440,000	46	240	430	ND	1.3	100	9640
31-86	Dry										
32-86	31,100	7,660	8,350	118,000	ND	199	122	ND	9.5	101	60.2

a. ND = Not Detected.

b. NA = Not Available.

c. NR = Not Requested.

TABLE 19. Other Inorganic Concentrations in Groundwater Monitoring Wells (Continued)

Station	Calcium ($\mu\text{g}/\ell$)	Magnesium ($\mu\text{g}/\ell$)	Potassium ($\mu\text{g}/\ell$)	Sodium ($\mu\text{g}/\ell$)	Bicarbonate (mg/ℓ)	Carbonate (mg/ℓ)	Chloride (mg/ℓ)	Cyanide (mg/ℓ)	Phosphate (mg/ℓ)	Sulfate (mg/ℓ)	Nitrate (mg/ℓ)
33-86	Dry										
34-86	388,000	30,000	7,800	170,000	14	400	47	ND	2.2	1,000	<5.0
35-86	170,000	68,000	2,310	182,000	61	720	110	ND	2.6	200	<5.0
36-86	Dry										
37-86	Dry										
38-86	Dry										
39-86	110,000	9,570	1,780	17,300	6	270	36	ND	2.2	74	<5.0
40-86	Dry										
41-86	96,900	15,600	3,720	51,300	15	360	34	ND	12	100	<5.0
42-86	122,000	11,900	1,730	13,400	27	350	50	ND	2.6	22	30.2
43-86	Dry										
44-86	54,500	6,470	3,600	22,000	NR	NR	12	NR	NR	NR	24.8
45-86	26,200	5,900	623	13,400	12	110	6.1	ND	4.7	14	<5.0
46-86	13,900	1,190	7,200	31,400	NA	NA	NA	NA	NA	NA	NA
47-86	15,400	2,230	ND ^a	164,000	5.4	88	2.9	ND	8.7	20	<5.0
48-86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
49-86	35,200	7,640	ND	29,500	7.0	45	30	ND	4.4	29	14.8
50-86	30,000	5,430	1,490	12,100	130	ND	7.6	ND	2.0	16	37.4
51-86	12,300	1,920	1,070	21,400	ND	42	7.3	ND	4.7	31	18.4
52-86	NA ^b	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
53-86	Dry										
54-86	43,300	10,400	6,030	36,800	8.8	257	15	ND	4.7	31	18.4
55-86	22,800	4,280	4,700	8,770	17	76	7.4	ND	3.3	22	<5.0
56-86	26,300	6,210	1,600	17,800	16	120	15	ND	ND	15	<5.0
57-86	Dry										
58-86	Dry										
59-86	112,000	36,100	41,300	156,000	30	510	92	NR	1.2	190	<5.0
61-86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
62-86	26,200	3,620	44,500	62,200	ND	200	26	ND	2.8	58	<5.0
63-86	Dry										
64-86	Dry										
65-86	93,100	24,200	1,840	98,300	25	370	70	ND	0.9	220	<5.0
66-86	Dry										
67-86	49,800	23,200	ND	63,400	9.7	345	35	ND	ND	65	<5.0
68-86	28,500	7,380	1,700	56,300	31	210	16	ND	4.7	37	55
69-86	144,000	40,400	54,800	163,000	38	410	130	ND	2.2	320	<5.0
70-86	42,900	8,680	13,700	41,800	ND	340	13	ND	1.2	72	<5.0
WS-1	26,000	8,880	ND	8,000	61	38	4.3	ND	1.8	39	23
WS-2	Dry										

a. ND = Not Detected.

b. NA = Not Available.

c. NR = Not Requested.

of strontium concentrations will include analysis for radioactive strontium-90 as well as for total metallic strontium. Monthly water level measurements will be made in all wells to better characterize the groundwater flow patterns in the Rocky Flats Alluvium and the Arapahoe Formation.

All potential contamination source areas have been identified and detailed plans for contamination source and plume characterization have been prepared. Remedial investigations are scheduled to begin in March 1978. These investigations will delineate the extent and magnitude of groundwater contamination at high priority sites. Feasibility studies are planned following completion of the remedial investigations in order to develop effective remedial action measures as warranted at particular sites.

F. Regional Water Monitoring

Regional water monitoring includes sampling and analysis of public water supplies and tap water from several surrounding communities. Of the regional water supplies, only Great Western Reservoir and Standley Lake receive runoff from the Rocky Flats drainage systems (Figure 4). The Rocky Flats contributions to radionuclides in regional water supplies through airborne emissions were estimated in the Plant Environmental Impact Statement.(US80a) These contributions were insignificant compared to contributions from fallout and natural background.

Water samples were collected weekly during 1986 from Great Western Reservoir, a water supply for the city of Broomfield, and from Standley Lake, a water supply for the city of Westminster and portions of the cities of Thornton and Northglenn. The weekly samples were composited into a monthly sample, and analyses were performed for plutonium, uranium and americium concentrations. Tritium analysis was conducted for each weekly sample. Annual grab samples were also collected from three regional reservoirs (Ralston, Dillon, and Boulder) and one stream (South Boulder Diversion Canal) at distances ranging from 1.6 to 96 kilometers (1 to 60 miles) from the

plant. These samples were collected to determine background data for plutonium, uranium, americium, and tritium in water. These data are presented in Tables 20 and 21.

Drinking water from Boulder, Broomfield, and Westminster was collected weekly, acidified, composited monthly, and analyzed for plutonium, uranium, and americium. Tritium analyses were performed on weekly grab samples. Quarterly grab samples of tap water were collected from the surrounding communities of Arvada, Denver, Golden, Lafayette, Louisville, and Thornton. Samples were analyzed for plutonium, uranium, americium, and tritium. These data are presented in Tables 20 and 21.

Evaluation of the regional reservoir and drinking water data indicates no unusual results. The plutonium, uranium, americium, and tritium concentrations for the regional reservoirs represented a small fraction (0.4 percent or less) of the DOE Derived Concentration Guides (DCGs). The average plutonium concentration in Great Western Reservoir was $0.008 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$ ($3.0 \times 10^{-4} \text{ Bq}/\ell$). This value is in the range of concentrations predicted for Great Western Reservoir in the Plant Environmental Impact Statement.(US80a) The values given in the Environmental Impact Statement are based on known low-level plutonium concentrations in the reservoir sediments. Results of the 1986 plutonium, uranium, americium, and tritium data for drinking water in nine communities were within the background range. All drinking water values were 0.3 percent or less of the applicable DCG.

Drinking water standards have been adopted by the State of Colorado(Co77) and the Environmental Protection Agency (EPA)(Fe76) for alpha-emitting radionuclides (excluding uranium and radon) and for tritium. These standards are $15 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$ and $20,000 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$ ($5.55 \times 10^{-1} \text{ Bq}/\ell$ and $740 \text{ Bq}/\ell$) respectively. During 1986, the sum of the average concentrations of plutonium and americium (alpha-emitting radionuclides) for each community tap water location was $0.02 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$ ($0.7 \times 10^{-3} \text{ Bq}/\ell$) or less. That value is 0.1 percent or less of the EPA and State of Colorado

TABLE 20. Plutonium, Uranium, and Americium Concentrations in Public Water Supplies

Location	Number of Analyses	C _{min}	C _{max}	C _{mean}	Percent of DCG
Plutonium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$)^a					
Reservoir					
Boulder	1	0.01 \pm 0.01	0.01 \pm 0.01	0.01 \pm 0.01	0.003
Dillon	1	0.02 \pm 0.03	0.02 \pm 0.03	0.02 \pm 0.03	0.007
Great Western	12	-0.002 \pm 0.005	0.03 \pm 0.01	0.008 \pm 0.002	0.003
Ralston	1	0.01 \pm 0.02	0.01 \pm 0.02	0.01 \pm 0.02	0.003
South Boulder Diversion Canal	1	0.00 \pm 0.02	0.00 \pm 0.02	0.00 \pm 0.02	<0.001
Standley	12	-0.004 \pm 0.005	0.006 \pm 0.005	0.002 \pm 0.001	<0.001
Drinking Water					
Arvada	4	0.00 \pm 0.02	0.05 \pm 0.03	0.02 \pm 0.01	0.007
Boulder	12	-0.002 \pm 0.006	0.03 \pm 0.01	0.004 \pm 0.002	0.001
Broomfield	12	-0.02 \pm 0.02	0.02 \pm 0.01	0.002 \pm 0.002	<0.001
Denver	4	0.00 \pm 0.02	0.03 \pm 0.02	0.02 \pm 0.01	0.007
Golden	4	0.00 \pm 0.02	0.07 \pm 0.02	0.02 \pm 0.01	0.007
Lafayette	4	0.00 \pm 0.02	0.02 \pm 0.01	0.01 \pm 0.01	0.003
Louisville	4	0.00 \pm 0.02	0.02 \pm 0.02	0.01 \pm 0.01	0.003
Thornton	4	-0.01 \pm 0.02	0.02 \pm 0.02	0.01 \pm 0.01	0.003
Westminster	12	-0.003 \pm 0.006	0.008 \pm 0.006	0.002 \pm 0.002	<0.001
Uranium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$)^b					
Reservoir					
Boulder	1	1.0 \pm 0.2	1.0 \pm 0.2	1.0 \pm 0.2	0.2
Dillon	1	0.9 \pm 0.2	0.9 \pm 0.2	0.9 \pm 0.2	0.2
Great Western	12	1.5 \pm 0.2	3.2 \pm 0.3	2.1 \pm 0.1	0.4
Ralston	1	1.4 \pm 0.2	1.4 \pm 0.2	1.4 \pm 0.2	0.3
South Boulder Diversion Canal	1	0.4 \pm 0.1	0.4 \pm 0.1	0.4 \pm 0.1	0.08
Standley	12	1.0 \pm 0.2	2.7 \pm 0.3	1.8 \pm 0.1	0.4
Drinking Water					
Arvada	4	0.0 \pm 0.1	1.1 \pm 0.2	0.4 \pm 0.1	0.08
Boulder	12	0.0 \pm 0.1	1.2 \pm 0.2	0.1 \pm 0.1	0.02
Broomfield	12	0.8 \pm 0.2	2.5 \pm 0.3	1.4 \pm 0.2	0.3
Denver	4	0.3 \pm 0.1	2.4 \pm 0.3	1.3 \pm 0.1	0.3
Golden	4	0.6 \pm 0.2	3.0 \pm 0.3	1.5 \pm 0.1	0.3
Lafayette	4	0.0 \pm 0.1	0.2 \pm 0.1	0.1 \pm 0.1	0.02
Louisville	4	-0.1 \pm 0.1	0.01 \pm 0.07	-0.02 \pm 0.05	<0.001
Thornton	4	0.8 \pm 0.1	2.7 \pm 0.3	1.7 \pm 0.1	0.3
Westminster	12	0.3 \pm 0.1	1.4 \pm 0.2	0.71 \pm 0.04	0.1
Americium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$)^c					
Reservoir					
Boulder	1	-0.04 \pm 0.06	-0.04 \pm 0.06	-0.04 \pm 0.06	<0.001
Dillon	1	0.01 \pm 0.07	0.01 \pm 0.07	0.01 \pm 0.07	0.02
Great Western	12	-0.01 \pm 0.02	0.08 \pm 0.08	0.006 \pm 0.008	0.01
Ralston	1	-0.02 \pm 0.06	-0.02 \pm 0.06	-0.02 \pm 0.06	<0.001
South Boulder Diversion Canal	1	0.01 \pm 0.08	0.01 \pm 0.08	0.01 \pm 0.08	0.02
Standley	12	-0.02 \pm 0.07	0.01 \pm 0.02	-0.001 \pm 0.008	<0.001
Drinking Water					
Arvada	4	-0.05 \pm 0.06	0.02 \pm 0.07	0.00 \pm 0.03	<0.001
Boulder	12	-0.02 \pm 0.07	0.02 \pm 0.02	-0.003 \pm 0.008	<0.001
Broomfield	12	-0.02 \pm 0.07	0.01 \pm 0.02	-0.002 \pm 0.008	<0.001
Denver	4	-0.05 \pm 0.06	-0.01 \pm 0.07	-0.02 \pm 0.03	<0.001
Golden	4	-0.04 \pm 0.07	0.02 \pm 0.06	-0.02 \pm 0.03	<0.001
Lafayette	4	-0.05 \pm 0.06	0.02 \pm 0.07	-0.02 \pm 0.03	<0.001
Louisville	4	-0.05 \pm 0.06	0.01 \pm 0.07	-0.02 \pm 0.03	<0.001
Thornton	4	-0.04 \pm 0.06	0.05 \pm 0.08	0.01 \pm 0.03	0.02
Westminster	12	-0.01 \pm 0.01	0.05 \pm 0.02	0.008 \pm 0.008	0.01

a. Radiochemically determined as plutonium-239 and -240. The interim standard calculated

Derived Concentration Guide (DCG) for plutonium in water offsite is 300×10^{-9} $\mu\text{Ci}/\text{mL}$. (See Appendix A.)

b. Radiochemically determined as uranium-233, -234, and -238. The interim standard calculated

Derived Concentration Guide (DCG) for uranium in water offsite is 500×10^{-9} $\mu\text{Ci}/\text{mL}$. (See Appendix A.)c. Radiochemically determined as americium-241. The interim standard calculated Derived Concentration Guide (DCG) for americium in water offsite is 60×10^{-9} $\mu\text{Ci}/\text{mL}$. (See Appendix A.)

TABLE 21. Tritium Concentrations in Public Water Supplies

Location	Number of Analyses	C _{min}	C _{max}	C _{mean}	Percent of DCG
<u>Reservoir</u>		Tritium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{mL}$) ^a			
Boulder	1	200 \pm 400	200 \pm 400	200 \pm 400	0.01
Dillon	1	0 \pm 400	0 \pm 400	0 \pm 400	<0.001
Great Western	49	-600 \pm 400	900 \pm 900	100 \pm 100	0.005
Ralston	1	0 \pm 400	0 \pm 400	0 \pm 400	<0.001
South Boulder Diversion Canal	1	200 \pm 500	200 \pm 500	200 \pm 500	0.01
Standley	49	-700 \pm 400	900 \pm 800	100 \pm 100	0.005
<u>Drinking Water</u>					
Arvada	4	0 \pm 400	300 \pm 500	100 \pm 200	0.005
Boulder	49	-700 \pm 600	800 \pm 400	100 \pm 100	0.005
Broomfield	49	-600 \pm 400	800 \pm 800	100 \pm 100	0.005
Denver	4	-400 \pm 500	100 \pm 400	-200 \pm 200	<0.001
Golden	4	200 \pm 400	500 \pm 500	300 \pm 200	0.02
Lafayette	4	-100 \pm 400	500 \pm 500	200 \pm 200	0.01
Louisville	4	-300 \pm 400	300 \pm 400	-100 \pm 200	<0.001
Thornton	4	-200 \pm 400	800 \pm 500	300 \pm 200	0.02
Westminster	49	-600 \pm 400	600 \pm 700	100 \pm 100	0.005

a. The offsite Derived Concentration Guide (DCG) for tritium in water is $2,000,000 \times 10^{-9}$ $\mu\text{Ci}/\text{mL}$.

The EPA and State of Colorado Primary Drinking Water Regulation limits for tritium are $20,000 \times 10^{-9}$ $\mu\text{Ci}/\text{mL}$.

drinking water standard for alpha activity. The average tritium concentrations in Great Western Reservoir, Standley Lake, and in all community tap water samples was 300×10^{-9} $\mu\text{Ci}/\text{mL}$ (11.1 Bq/L) or less. That value is typical of background tritium concentrations in Colorado and represents 1.5 percent or less of the State of Colorado and EPA Drinking Water Standard for tritium.(Co77, Fe76)

G. Soil Sampling and Analysis

Forty soil samples were collected in October 1986 at radial intervals of approximately 18 degrees and at approximate distances of 1.6 and 3.2 kilometers (1 and 2 miles) from the center of the plant. The soil samples were collected by driving a 10×10 centimeters (4×4 inches) cutting tool 5 centimeters (2 inches) into undisturbed soil.(Ro82) The soil sample within the tool cavity was removed and placed into a new one-gallon paint can. Five subsamples were collected from the corners and center of two one-meter squares, which were spaced one meter apart. Each set of ten subamples

was composited for the plutonium radiochemical analysis.

The plutonium in soil data for 1986 are summarized in Table 22 and displayed in Figure 11. Within the plant security area, plutonium concentrations were in the range from 0.03 to 15 pCi/g (1.11 to 555 Bq/kg). Outside the plant security area (mostly within the plant buffer zone) plutonium concentrations were in the range from 0.02 to 5.3 pCi/g (0.74 to 196 Bq/kg). The maximum onsite plutonium values were found in the soil samples from the eastern portion of the plant. These sample locations are due east of the known area of plutonium contamination. The plutonium concentrations measured in 1986 were similar to the same sites in 1984 and 1985. Data from 1984 and 1985 are included in Table 22 for comparison. The major exceptions are at site 1-090 and 2-090. Both sites have consistently yielded samples with plutonium concentrations in the 1-10 pCi/g range. A possible explanation for the variations seen for these locations is the existence of minute "hot

TABLE 22. Plutonium Concentration in Rocky Flats Area Soil Samples^a at One and Two Miles From the Plant

Location	1984 Pu (pCi/g) ^b	1985 Pu (pCi/g)	1986 Pu (pCi/g)	Location	1984 Pu (pCi/g)	1985 Pu (pCi/g)	1986 Pu (pCi/g)
1-018	0.08 ± 0.02	0.15 ± 0.02	0.15 ± 0.02	2-018	0.00 ± 0.01	0.04 ± 0.01	0.03 ± 0.01
1-036	0.03 ± 0.01	0.08 ± 0.01	0.10 ± 0.02	2-036	0.02 ± 0.01	0.02 ± 0.01	0.07 ± 0.01
1-054	0.00 ± 0.01	0.02 ± 0.01	0.04 ± 0.01	2-054	0.03 ± 0.01	0.03 ± 0.01	0.05 ± 0.01
1-072	0.60 ± 0.05	0.32 ± 0.03	0.63 ± 0.06	2-072	0.40 ± 0.04	0.33 ± 0.03	0.23 ± 0.02
1-090	7.7 ± 0.5	1.0 ± 0.09	7.4 ± 0.62	2-090	10.0 ± 0.6	2.5 ± 0.25	5.3 ± 0.48
1-108	15.0 ± 0.9	13.0 ± 1.3	15 ± 1.4	2-108	0.46 ± 0.04	0.41 ± 0.04	0.46 ± 0.04
1-126	2.1 ± 0.1	1.9 ± 0.17	1.9 ± 0.18	2-126	0.14 ± 0.02	0.42 ± 0.04	0.44 ± 0.05
1-144	0.29 ± 0.03	0.32 ± 0.03	0.27 ± 0.02	2-144	0.02 ± 0.01	0.04 ± 0.01	0.04 ± 0.01
1-162	0.14 ± 0.02	0.10 ± 0.01	0.08 ± 0.01	2-162	0.00 ± 0.01	0.01 ± 0.00	0.02 ± 0.01
1-180	0.09 ± 0.02	0.06 ± 0.01	0.06 ± 0.01	2-180	0.02 ± 0.01	0.11 ± 0.01	0.04 ± 0.01
1-198	0.22 ± 0.03	0.16 ± 0.02	0.16 ± 0.02	2-198	0.05 ± 0.02	0.02 ± 0.01	0.08 ± 0.01
1-216	0.05 ± 0.02	0.05 ± 0.01	0.10 ± 0.01	2-216	0.04 ± 0.01	0.04 ± 0.01	0.06 ± 0.01
1-234	0.13 ± 0.02	0.05 ± 0.01	0.04 ± 0.01	2-234	0.04 ± 0.01	0.05 ± 0.01	0.05 ± 0.01
1-252	0.17 ± 0.02	0.14 ± 0.02	0.11 ± 0.01	2-252	0.09 ± 0.01	0.04 ± 0.01	0.07 ± 0.01
1-270	0.06 ± 0.02	0.07 ± 0.01	0.08 ± 0.01	2-270	0.04 ± 0.01	0.04 ± 0.01	0.06 ± 0.01
1-288	0.04 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	2-288	0.01 ± 0.01	0.04 ± 0.01	0.05 ± 0.01
1-306	0.14 ± 0.02	0.09 ± 0.01	0.17 ± 0.02	2-306	0.00 ± 0.01	0.06 ± 0.01	0.02 ± 0.01
1-324	0.13 ± 0.02	0.15 ± 0.02	0.21 ± 0.02	2-324	0.08 ± 0.02	0.04 ± 0.01	0.09 ± 0.01
1-342	0.04 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	2-342	0.13 ± 0.02	0.13 ± 0.01	0.12 ± 0.01
1-360	0.10 ± 0.02	0.11 ± 0.01	0.19 ± 0.02	2-360	0.02 ± 0.01	0.09 ± 0.01	0.05 ± 0.01

a. Sampled to a depth of 5 cm.

b. Concentrations are for the fraction of soil measuring less than 2 mm in diameter.

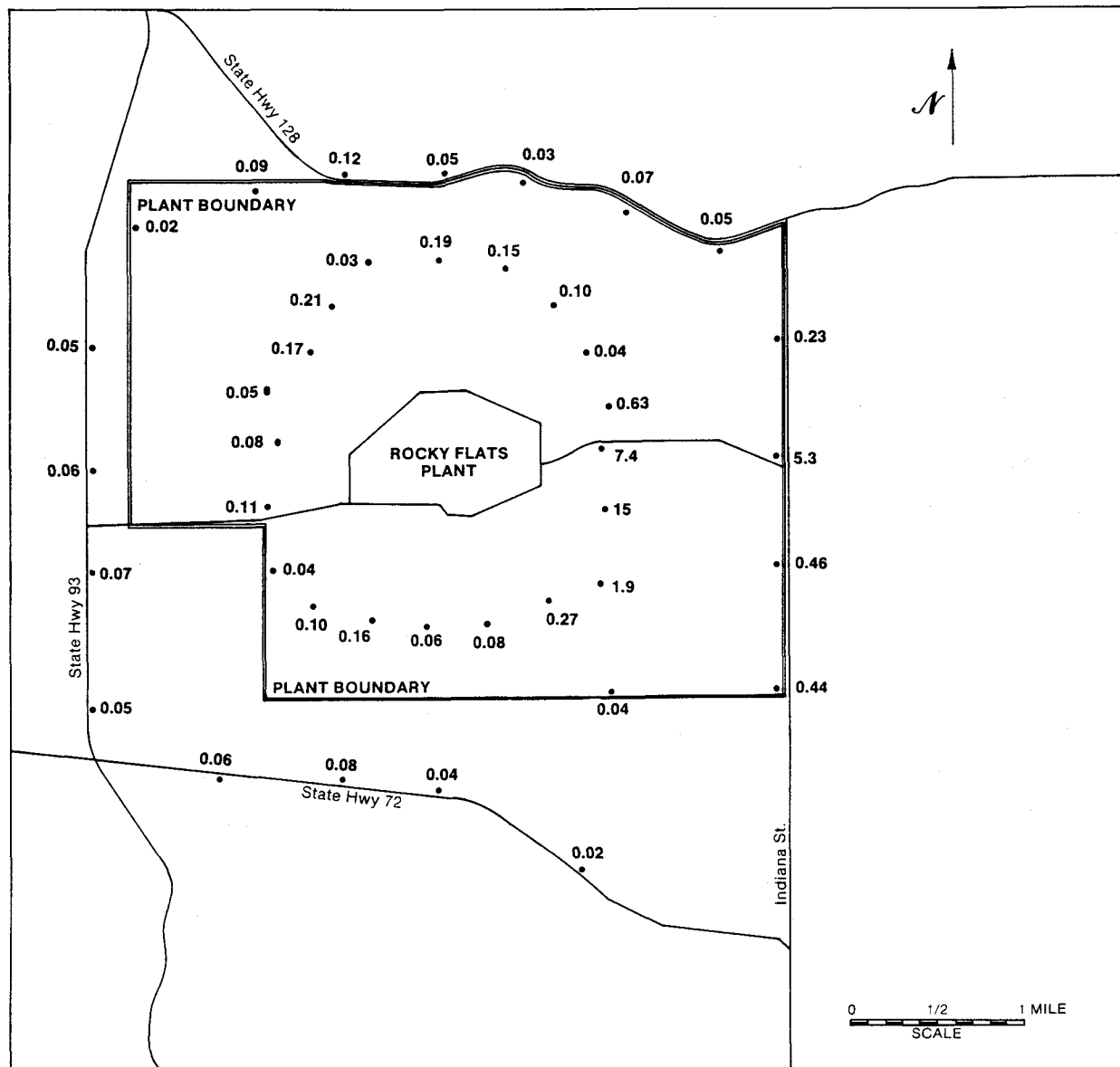


FIGURE 11. Plutonium Concentrations in Soil
(Values in Picocuries Per Gram)

particles" in these two areas of elevated plutonium in soil concentrations.

H. External Gamma Radiation Dose Monitoring

Thermoluminescent dosimeters (TLDs) are used to measure external penetrating gamma radiation exposure at 47 locations on and off the plantsite. Replicate TLDs are located at each site. All TLDs are exposed for three months. The TLDs are

placed at 19 locations within the property enclosed by the security fence shown in Figure 1. Measurements are also made at 16 perimeter locations 3 to 6 kilometers (2 to 4 miles) from the plant and in 12 communities located within 50 kilometers (30 miles) of the plant. The TLDs are placed at a height of 1 meter (3 feet) above ground level.

During 1983, conversion from a Harshaw TLD system to a Panasonic system was initiated. For

one complete calendar year, two TLDs of each type were used at each monitoring location. Beginning in 1984, only the Panasonic TLDs were used.

The environmental TLDs consist of two Panasonic 802 dosimeters, each of which has four elements. Only one of the elements of each dosimeter is used. This element consists of $\text{CaSO}_4:\text{Tm}$ deposited on a polyimide surface. The phosphor is covered with a clear Teflon, and backed with an opaque ABS plastic. The TLDs are packaged in a small plastic bag, a paper envelope, and another plastic bag to protect them from the weather. Total filtration over the phosphor is 178.5 mg/cm^2 .

The environmental dosimeters have been individually calibrated (three times each) against an onsite Cs-137 gamma calibration source. Calibration linearity studies have confirmed that TLD response is linear for exposure levels ranging from 10 mrem to 1,000 mrem. The average calibration factor for each dosimeter is applied to measurements taken with that dosimeter. An additional correction is applied to correct for day-to-day variations in reader calibration.

It was determined that a statistically significant ($p = 0.05$) difference in response exists between the Harshaw environmental monitoring system used prior to 1984, and the Panasonic environmental monitoring systems used beginning in 1984. In order to compare the 1986 values with the previously reported Harshaw data, it is necessary to multiply the Panasonic results given in Table 23 by 1.046.

The annual dose equivalent was calculated by summing the quarterly measurements at each location and then determining a mean annual dose equivalent for the three location categories: onsite, perimeter, and community.

In previous Annual Reports, the Annual Measured Dose was reported with a 95 percent confidence interval on the mean using the standard error of the mean, calculated from the variance of the individual measured values. Beginning in 1985, the 95 percent confidence interval on an individual observation within each location category - calculated as 1.96 standard deviations - was added to the report. This latter interval may be used for assessing the variability of the individual location measurements within a location category.

The 1986 environmental measurements using TLDs are summarized in Table 23. The average annual dose equivalents, as measured onsite, in the perimeter environs, and in communities, were 137, 145, and 171 mrem (1.37, 1.45, and 1.71 mSv), respectively. These values are indicative of background gamma radiation in the area. (Na75)

V. ASSESSMENT OF POTENTIAL PLANT CONTRIBUTION TO PUBLIC RADIATION DOSE

In August 1985, the Department of Energy (DOE) adopted an interim radiation protection standard for DOE environmental activities to be implemented in CY1985. (Va85) This interim standard incorporates guidance from the National Council on

TABLE 23. Environmental Thermoluminescent Dosimeter Measurements

Location Category	Number of Locations	Number of Measurements	Mean Annual Measured Dose (mrem)	95% Confidence Interval on the Mean (mrem) ^a	95% Confidence Interval on an Individual Measurement (mrem) ^b
Onsite	19	147	137	± 6	± 66
Perimeter	16	127	145	± 4	± 46
Community	12	95	171	± 5	± 48

a. Calculated as 1.96 standard deviations of the mean ($1.96 \sigma_{\bar{x}}$).

b. Calculated as 1.96 standard deviations of the individual measurements ($1.96 \sigma_x$).

Radiation Protection and Measurements (NCRP), as well as the Environmental Protection Agency air emission standards of 40 CFR 61, Subpart H. Included in the interim standard is a revision of the dose limits for members of the public and tables of radiation dose conversion factors to be used for calculating dose from intakes of radioactive materials. The dose factors are based on the International Commission on Radiological Protection (ICRP) Publication 30 methodology for radiation dosimetry. The DOE interim standard and the dose conversion factor tables have been used in this 1986 "Annual Environmental Monitoring Report" for assessment of the potential Rocky Flats Plant contribution to public radiation dose. As in past Annual Reports, the dose limits and dose conversion factors used are specified, and comparisons can be made with information in past Annual Reports to determine the magnitude of the changes.

Potential public radiation dose commitments, which could have resulted from plant operations, were calculated from average radionuclide concentrations measured at the DOE property boundary and in surrounding communities. Inhalation, water ingestion, and ground-plane irradiation are the principal pathways of exposure. Swimming and consumption of foodstuffs are

insignificant pathways. This latter finding is to be expected because of limited swimming and fishing in the area and because most locally consumed food is produced at considerable distances from the plant.

The dose assessment for 1986 was conducted for several locations: the Rocky Flats Plant Property (site) boundary, nearby communities, and sites to a distance of 80 kilometers (50 miles). Dose conversion factors used for the inhalation and water ingestion pathways were derived from the tables provided by DOE.(Va85) The relative abundances of plutonium and americium isotopes in plutonium used at Rocky Flats (shown in Table 24) were used to calculate composite dose conversion factors for inhalation. The fractions of ingested radionuclides that are absorbed from the gastrointestinal tract and the lung clearance classes for inhaled radionuclides were chosen to maximize the associated dose conversion factors. The inhalation rate of 2.66×10^{-4} m³/s and the water ingestion rate of 2 liters (2.1 quarts) per day were derived from data for reference man and were included in the factors.(In75) Each of these dose conversion factors is for a 50-year dose commitment from one year of chronic exposure. Ground-plane irradiation dose conversion factors are from published data by D. C. Kocher.(Ko81,

TABLE 24. Isotopic Composition of Plutonium Used at Rocky Flats(US80a)

Isotope	Relative Weight (Percent)	Specific Activity (Ci/g)	Relative Activity ^a (Ci)	Fraction of Pu Alpha Activity ^b
Pu-238	0.01	17.1	0.00171	0.0233
Pu-239	93.79	0.0622	0.05834	0.7962
Pu-240	5.80	0.228	0.01322	0.1804
Pu-241	0.36	103.5*	0.37260	5.085
Pu-242	0.03	0.00393	1.18×10^{-6}	1.61×10^{-5}
Am-241	—	—	—	0.20 ^c

*Beta Activity.

a. Obtained by multiplying the percent by weight by the specific activity.

b. Obtained by dividing the relative activity by the sum of the relative activities for the plutonium alpha emitters.

c. The value for Am-241 is taken to be 20% of the plutonium alpha activity.

Ko83) The dose conversion factors used in this report are listed in Table 25.

A. Dose Assessment Source Terms

Plutonium and americium in the Rocky Flats environs are the combined result of fallout deposition from global atmospheric nuclear weapons testing and past releases from the plant. Uranium, a naturally occurring element, is indigenous to many parts of Colorado and also is used in plant operations in various isotopic ratios. Tritium, a radionuclide formed by natural processes, also is associated with plant operations.

Inhalation source terms for the 1986 dose assessment were based on plutonium-239 and -240 concentrations measured in ambient air samples. Although it is known that much of this plutonium in air is from residual fallout from past global atmospheric weapons testing, for the purpose of this dose assessment it was assumed that all of the plutonium originated from the Rocky Flats Plant. The ingestion source terms were based on measured concentrations of plutonium, americium, uranium, and tritium in water. The ground-plane source terms were based on measured values of

plutonium in soil and an assumed ratio of 0.20 for the americium to plutonium alpha activity in the soil. This ratio is the maximum level of americium in-growth from Rocky Flats plutonium.(US80a)

The maximum site-boundary dose assessment assumes that an individual is continuously present at the plant perimeter, which actually is uninhabited. The plutonium inhalation source term of 2.7×10^{-17} $\mu\text{Ci}/\text{m}^3$ (1.0×10^{-6} Bq/m^3) was the maximum annual average concentration of plutonium-239 and -240, as measured for a single location in the perimeter ambient air sampling network.

The water supply for the individual at the site boundary was assumed to be Walnut Creek, which intermittently flows offsite and provides the liquid effluent source term at the site boundary. During 1986, the plutonium concentration in Walnut Creek averaged 1.3×10^{-11} $\mu\text{Ci}/\text{m}^3$ (4.8×10^{-4} Bq/ℓ). The average americium concentration was 7.0×10^{-12} $\mu\text{Ci}/\text{m}^3$ (2.6×10^{-4} Bq/ℓ). These concentrations were used as the water ingestion source term for the maximum site boundary dose assessment. The average concentration of uranium in Walnut Creek was 5.6×10^{-9} $\mu\text{Ci}/\text{m}^3$ (2.1×10^{-1} Bq/ℓ) while the average concentration in

TABLE 25. Dose Conversion Factors Used in Assessment Calculations

Organ	Inhalation ^{a, b} ($\frac{\text{rem}\cdot\text{milliliter}}{\text{microcurie}}$)		Water Ingestion ^{a, c} ($\frac{\text{rem}\cdot\text{milliliter}}{\text{microcurie}}$)		Ground-Plane Irradiation ^d ($\frac{\text{rem}\cdot\text{square meter}}{\text{microcurie}}$)	
	Pu-239, -240	Pu-239, -240	Am-241	U-233, -234, -238	Pu-239, -240	Am-241
Effective Dose Equivalent	5.57×10^{12}	3.14×10^5	1.63×10^6	1.68×10^5	8.92×10^{-5}	3.05×10^{-3}
Liver	2.17×10^{13}	1.17×10^6	6.21×10^6	(e)	4.85×10^{-6}	1.78×10^{-3}
Bone Surfaces	1.02×10^{14}	5.69×10^6	2.97×10^7	2.70×10^6	2.01×10^{-5}	3.69×10^{-3}
Lung	1.06×10^{13}	(f)	(f)	(f)	1.20×10^{-5}	2.01×10^{-3}

a. Inhalation and water ingestion dose conversion factors were adopted from DOE and are for a 50-year dose commitment period and a 1- μm Activity Median Aerodynamic Diameter (AMAD) particle size (Va85) GI absorption fractions and lung clearance classes were chosen to maximize the dose conversion factors.

b. An inhalation rate of 2.66×10^3 m^3/s for 1 year was assumed.

c. A water intake rate of 2×10^3 m^3 (2.1 quarts) per day for 1 year was assumed.

d. Ground plane irradiation dose conversion factors were adopted from D. C. Kocher.(Ko81, Ko83) For Pu-239, -240, the higher of the factors for the two isotopes was used.

e. The liver receives no significant dose from this pathway.

f. The lung receives no significant dose from this pathway.

incoming raw water was 1.0×10^{-9} $\mu\text{Ci}/\text{mL}$ (3.7×10^{-2} Bq/ℓ). The source term for uranium ingestion was the difference between these two values [4.6×10^{-9} $\mu\text{Ci}/\text{mL}$ (1.7×10^{-1} Bq/ℓ)]. The average tritium concentration in Walnut Creek was 2.0×10^{-7} $\mu\text{Ci}/\text{mL}$ (7.4 Bq/ℓ), which is within the background range typically measured in regional waters. This concentration of tritium is an insignificant contributor to dose. Tritium in the water was, therefore, omitted from the dose assessment.

The ground-plane irradiation source term is based on the maximum plutonium in soil deposition at the plant perimeter, as reported by the Environmental Measurements Laboratory.(US70) This source term is 3×10^{-2} $\mu\text{Ci}/\text{m}^2$ (1×10^3 Bq/m^2). The americium is assumed to be present at an alpha activity level of 20 percent of that of the plutonium, which is the maximum quantity of americium that can be present in Rocky Flats plutonium from the decay of plutonium-241.(US80a) The americium source term, therefore, is conservatively estimated to be 6×10^{-3} $\mu\text{Ci}/\text{m}^2$ (2×10^2 Bq/m^2).

Source terms and corresponding dose commitments were evaluated for each of the surrounding communities to determine the maximum community exposure. Ground-plane irradiation and water ingestion pathways were insignificant for all of the communities. The only significant pathway for radiation exposure was inhalation of plutonium in air. The source term for inhalation used in the dose assessment was the maximum annual average plutonium concentration measured in community ambient air [2×10^{-17} $\mu\text{Ci}/\text{mL}$ (7.4×10^{-7} Bq/m^3)]. This concentration was the annual average concentration measured in the Golden ambient air sampler.

A summary of the source terms for the maximum site boundary and for community locations is tabulated in Table 26.

B. Maximum Site Boundary Dose

The maximum dose to an individual continuously present at the site boundary is based on the radionuclide concentrations shown in Table 26. From these concentrations and the dose conversion factors in Table 25, a 50-year dose commitment of 9.6×10^{-4} rem (9.6×10^{-6} Sv) is calculated as the effective dose equivalent from all pathways. The corresponding bone surfaces dose is 1.5×10^{-2} rem (1.5×10^{-4} Sv). The Department of Energy (DOE) interim radiation protection standard for members of the public for prolonged periods of exposure is 0.1 rem per year (1×10^{-3} Sv per year) effective dose equivalent. The interim standard for the air pathway only is 7.5×10^{-2} rem per year (7.5×10^{-4} Sv per year) for any organ for internally deposited radionuclides.(Va85) The maximum site boundary dose represents 0.96 percent of the standard for all pathways for the effective dose equivalent. If all of the dose were received from the air pathway, it would represent 20 percent of the air emission standard for any organ.

C. Maximum Community Dose

Based on radionuclide concentrations in surrounding communities (Table 26), the calculated 50-year dose commitments are 1.1×10^{-4} rem (1.1×10^{-6} Sv) effective dose equivalent and 2.0×10^{-3} rem (2.0×10^{-5} Sv) to bone surfaces. These values represent 0.11 percent of the DOE interim standard for effective dose equivalent and

TABLE 26. Radioactivity Concentrations Used for 1986 Dose Calculations

Location	Air ($\mu\text{Ci}/\text{mL}$)	Water ($\mu\text{Ci}/\text{mL}$)			Surface Deposition ($\mu\text{Ci}/\text{m}^2$)	
	Pu-239, -240	Pu-239, -240	Am-241	U-233, -234	Pu-239, -240	Am-241
Maximum Site Boundary	2.7×10^{-17}	1.3×10^{-11}	7.0×10^{-12}	4.6×10^{-9}	3×10^{-2}	6×10^{-3}
Community	2.0×10^{-17}	-	-	-	-	-

2.7 percent of the air emission standard for any organ.

The maximum site boundary and community 50-year committed dose equivalents are summarized in Table 27. The effective dose equivalents may be compared to an average annual effective dose equivalent for the Denver area of about 2.6×10^{-1} rem (2.6×10^{-3} Sv) from natural background radiation.(Na75, Na84, So84) (See Table 28.) This natural background radiation level for Denver is higher than that shown for the total body in past Annual Reports prior to 1985 and reflects the significant contribution to effective dose equivalent from inhaled indoor radon, as well as the adoption of the ICRP 30 methodology of radiation dosimetry.

D. Eighty-Kilometer Dose Estimates

The dose commitment for all individuals, to a distance of 80 kilometers (50 miles), is based on the calculated maximum community dose estimates shown in Table 27. The estimated committed effective dose equivalent is less than 1×10^{-3} rem or 1 mrem (1×10^{-5} Sv). A level of "1 mrem/yr" or less is specified as a *de minimis*

(inconsequential) level of exposure in the DOE Guide entitled, "A Guide to Reducing Radiation Exposure to As Low As Reasonably Achievable (ALARA)."(Us80b) The Guide further states:

"Radiation-induced mutations and diseases have not been discovered in populations that are or have been exposed to doses of 100 mrem/yr or less. Hence, it is reasonable to suggest that no health effects will be discerned if a population is exposed to an additional 1 percent of the level; i.e., 1 mrem/yr. An annual dose of 1 mrem should be regarded as a level which is clearly *de minimis*."

Based on the *de minimis* concept in the Guide and on the maximum community dose estimates, the dose commitment for all individuals to 80 kilometers is considered to be *de minimis*.

The Environmental Protection Agency (EPA) requires that approved EPA procedures be used to demonstrate compliance with its radioactivity air emissions standards found in 40 CFR 61, Subpart H. At the writing of this Report, the only procedure for which the EPA has published approval is modeling of radioactivity air emissions

TABLE 27. Fifty-Year Committed Dose Equivalent From One Year of Chronic Intake/Exposure

Source	Effective Dose Equivalent (rem)	Liver (rem)	Bone Surfaces (rem)	Lung (rem)
Maximum Site Boundary Location	9.6×10^{-4}	6.6×10^{-4}	1.5×10^{-3}	3.0×10^{-4}
Community	1.1×10^{-4}	4.3×10^{-4}	2.0×10^{-3}	2.1×10^{-4}

TABLE 28. Estimated Annual Natural Background Radiation Dose for the Denver Metropolitan Area(Na75, Na84, So84)

Source	Effective Dose Equivalent (rem)
Cosmic Radiation	0.050
Cosmogenic Nuclides	0.0015
Primordial Nuclides-External	0.072
Primordial Nuclides-Internal	0.1326
Total for one year (rounded)	0.26

data using the AIRDOS-EPA atmospheric dispersion/radiation dose calculation computer code.(US85) The Rocky Flats Plant is seeking EPA approval for using environmental (ambient) sampling as the basis for demonstrating compliance with 40 CFR 61, Subpart H. This is the procedure that is described above for calculating projected radiation doses to the public. Pending EPA approval of this procedure, the AIRDOS-

EPA computer code also has been used to calculate projected radiation doses to the public as a result of air emissions of radioactive materials from the Rocky Flats Plant. The results of this computer code calculation confirm that the maximum radiation dose to a member of the public as a result of exposure to airborne radioactivity from the Rocky Flats Plant in 1986 is less than 1 mrem effective dose equivalent.

VI. APPENDIXES

APPENDIX A
APPLICABLE GUIDES AND STANDARDS

The Rocky Flats Plant Environmental Monitoring Program includes evaluating plant compliance with all relevant guides, limits, and standards. Guide values for radionuclides in ambient air and waterborne effluents have been adopted by the Department of Energy (DOE), the Colorado Department of Health, and for the air pathway only by the Environmental Protection Agency (EPA). (Va85, Co78) The guides are based on recommendations published by the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP). Ambient air data for nonradioactive parameters is collected at Rocky Flats for comparison to the criteria pollutants listed under the EPA National Ambient Air Quality Standards, established by the Clean Air Act. (US81b) Instrumentation and methodology follow requirements established by EPA in the Quality Assurance Handbook for Air Pollution Measurement Systems. (US76) Limits for nonradioactive pollutants in effluent water have been defined by an EPA National Pollutant Discharge Elimination System (NPDES) discharge permit. (US84a) In 1976, the EPA also established standards for radionuclides in drinking water. (Fe76) These drinking water standards have been adopted, in turn, by the State of Colorado. (Co77)

In a memorandum of August 5, 1985, the DOE adopted an interim radiation protection standard for DOE environmental activities to be implemented in CY 1985. (Va85) This interim standard incorporates guidance from the NCRP, as well as the air emission standards of 40 CFR 61, Subpart H. Included in the interim standard is a revision of the dose limits for members of the public and tables of radiation dose conversion factors to be used for calculating dose from intakes of radioactive materials. The dose factors are based on ICRP Publication 30 methodology for radiation dosimetry. Effluent air and water concentration guides (secondary standards derived from the primary dose standards and calculated using dose

conversion factors and assumed air and water intake rates) were not included in the memorandum. In order to provide these secondary concentrations given in this report, we have calculated Derived Concentration Guides (DCGs) based on the interim standard dose limit for all pathways of 0.1 rem/year for a 50-year committed effective dose equivalent. The dose conversion factors provided in the August 5, 1985, memorandum were used and intake rates of 8400 cubic meters per year ($2.66 \times 10^{-4} \text{ m}^3/\text{s}$) for air and 730 liters per year (2 l/d) for water were assumed for the calculations. The calculated DCGs are given in Table A-1 and are comparable in concept to the Radioactivity Concentration Guides (RCGs) published by DOE for its previous radiation protection standard. (US81a)

The previous RCGs included permissible concentrations of specific radionuclides and mixtures of radionuclides in air (RCG_a) and water (RCG_w) for individuals in the general population. (US81a) In addition to restricting specific radionuclides, the guides restricted the concentration of radionuclides in a mixture such that the sum of the ratios of each radionuclide concentration to the appropriate concentration guide would not exceed a value of 1. The guides further stated that a radionuclide might be considered as not present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture to the concentration guide for that radionuclide did not exceed one tenth and (b) the sum of such ratios for all radionuclides considered as not present in the mixture did not exceed one fourth.

During 1986, average specific radionuclide concentrations in air and water for the Rocky Flats Plant were all less than one tenth of the appropriate Derived Guides for specific radionuclides. The sum of the ratios of those average concentrations to their respective DCGs was less than one fourth for all air and water sampling locations. Applying the same methodology for reporting mixtures under the DCG concept as was used with RCGs, the

measured concentrations in the tables have been compared to the concentration guides for specific radionuclides rather than to the guide for mixtures.

The fractions of ingested radionuclides that are absorbed in the gastro-intestinal tract and the lung clearance classes for inhaled radionuclides were chosen to yield the most restrictive DCGs for comparisons in this report. Throughout this report, where a radionuclide concentration is expressed as the cumulative measurement of more than one isotope, the stated DCG used for comparison represents the most restrictive DCG for that grouping of isotopes. Plutonium concentrations measured at Rocky Flats represent the alpha radioactivity from plutonium isotopes 239 and 240, which constitute over 97 percent of the alpha radioactivity in plutonium handled at the plant.

Reported uranium concentrations are the cumulative alpha activity from uranium-233, -234, and -238. Components containing fully enriched uranium are handled at the Rocky Flats Plant. Depleted uranium metal is fabricated and also is handled as process waste material. Uranium-235 is the major isotope by weight (93 percent) in fully enriched uranium; however, uranium-234 accounts for approximately 97 percent of the alpha activity of fully enriched uranium. In depleted uranium, the combined alpha activity from uranium-234 and -238 accounts for approximately 99 percent of the total alpha activity. The uranium DCGs used in this report for air and water are those for uranium-233, -234, and uranium-238, which are the most restrictive.

Environmental uranium concentrations can be measured by a variety of laboratory techniques. Nonradiological techniques yield concentration units of mass per unit volume such as $\mu\text{g}/\text{m}^3$ and $\mu\text{g}/\ell$. The uranium concentrations given in this report were derived by measuring radioactivity from alpha-emitting uranium isotopes and are expressed in terms of activity units per unit volume. Rocky Flats data include measurements of depleted uranium, fully enriched uranium, and natural uranium.

Conversion factors for specific types of uranium can be used to compare the data in this report to data from other facilities and agencies that are

given in units of mass per unit volume; however, the resulting approximations will not have the same assurance of accuracy as that for the original measured values. Uranium in effluent air from plant buildings is primarily depleted uranium. The conversion factor for these data is $2.6 \times 10^6 \text{ g/Ci}$. Natural uranium is the predominant form found in water. The conversion factor for water data is $1.5 \times 10^6 \text{ g/Ci}$.

The applicable EPA standard for beryllium (a nonradioactive material) in airborne effluents from plant buildings is 10 grams per stationary source in a 24-hour time period.(US78) For ambient air, the calculated DCG for plutonium-239 and -240 for members of the public is $20 \times 10^{-15} \mu\text{Ci}/\text{m}^3$ ($7.4 \times 10^{-4} \text{ Bq}/\text{m}^3$).

The calculated americium-241 DCG in waterborne effluents for members of the public is $60 \times 10^{-9} \mu\text{Ci}/\text{m}^3$ (2.2 Bq/ ℓ). The comparable DCG for plutonium-239, -240 in water is $300 \times 10^{-9} \mu\text{Ci}/\text{m}^3$ (11 Bq/ ℓ). The most restrictive calculated DCG for uranium-233, -234, and -238 in water is $500 \times 10^{-9} \mu\text{Ci}/\text{m}^3$ (19 Bq/ ℓ), which is the DCG for uranium-233. In waterborne effluents available to members of the public, the calculated DCG for tritium is $2,000,000 \times 10^{-9} \mu\text{Ci}/\text{m}^3$ (74,000 Bq/ ℓ).

In 1976, the EPA promulgated regulations for radionuclides in drinking water.(Fe76) These regulations were effective on June 24, 1977, along with primary drinking water regulations for microbiological, chemical, and physical contaminants. The intent of the Safe Drinking Water Act was to ensure that each state has primary responsibility for maintaining drinking water quality. To comply with these requirements, the Colorado State Board of Health modified existing State drinking water standards to include radionuclides.(Co77) Two of the community drinking water standards are of interest in this report. The State standard for gross-alpha activity (including radium-226 but excluding radon and uranium) in community water systems is a maximum of 15 pCi/ ℓ or $15 \times 10^{-9} \mu\text{Ci}/\text{m}^3$ ($5.6 \times 10^{-1} \text{ Bq}/\ell$). Americium and plutonium, which are alpha-emitting radionuclides, are included in this limit. The limit for tritium in drinking water is 20,000 pCi/ ℓ or $20,000 \times 10^{-9} \mu\text{Ci}/\text{m}^3$ (740 Bq/ ℓ).

The Rocky Flats Plant NPDES permit, which the EPA reissued in 1984 to DOE, established sanitary effluent limitations on discharge from Pond B-3 (sewage effluent), limitations for nitrate and pH in the discharge from Pond A-3 in the Walnut Creek drainage, limitations on discharge from the reverse osmosis pilot plant, on Woman Creek, limitations on discharge from the reverse osmosis plant, and control of sediment release during discharge from Ponds A-4, B-5, and C-2.

In addition to evaluating compliance with all relevant guides, limits, and standards, the Health, Safety and Environment Department assists operating groups in adhering to the DOE policy that "...operations shall be conducted in a manner to assure that radiation exposure to individuals and population groups is limited to the lowest levels technically and economically practicable."(US81a)

TABLE A-1. Applicable Standards for Radioactive and Nonradioactive Materials

Legend				
μCi	=	microcuries	40 CFR 61	= Code of Federal Regulations
m^3	=	cubic meters		National Emission Standards
$\text{m}\ell$	=	milliliters		for Hazardous Air
mg/ℓ	=	milligrams per liter		Pollutants (USEPA)
SU	=	standard units	NPDES	= National Pollutant Discharge
NA	=	not applicable		Elimination System
g	=	grams	CDH	= Colorado Department
				of Health

Parameter	Applicable Guides and Standards	Reference
Airborne Effluents		
Plutonium-239, -240	NA	NA
Uranium-233, -234, -238	NA	NA
Tritium	NA	NA
Beryllium	<10.0 g/day	40 CFR 61.32(a)
Ambient Air		
Plutonium-239, -240	$20.0 \times 10^{-15} \mu\text{Ci}/\text{m}\ell$	Calculated ^a
Waterborne Effluents (Radioactive)		
Plutonium-239, -240	$300 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$	Calculated ^a
Uranium-233, -234, -238	$500 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$	Calculated ^a
Americium-241	$60 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$	Calculated ^a
Tritium	$2,000,000 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$	Calculated ^a

Discharge Limitations ^b				
Parameter	Monthly Average	Weekly Average	Daily Maximum	Reference
Effluent Water Samples (Nonradioactive)				
pH		6.0-9.0 SU		NPDES Permit
Nitrates as N	10 mg/ℓ	20 mg/ℓ	NA	NPDES Permit
Total Phosphorus	8 mg/ℓ	NA	12 mg/ℓ	NPDES Permit
Biochemical Oxygen Demand, 5-Day	10 mg/ℓ	NA	25 mg/ℓ	NPDES Permit
Suspended Solids	30 mg/ℓ	45 mg/ℓ	NA	NPDES Permit
Total Chromium	0.05 mg/ℓ	NA	0.1 mg/ℓ	NPDES Permit
Residual Chlorine	NA	NA	0.5 mg/ℓ	NPDES Permit
Oil and Grease	NA	NA	Visual	NPDES Permit
Fecal Coliform - No./100 $\text{m}\ell$	200	400	NA	NPDES Permit
Total Organic Carbon	22 mg/ℓ	NA	30 mg/ℓ	NPDES Permit

a. Calculated on the basis of DOE August 5, 1985, memorandum using DOE dose limit of 0.1 rem/yr to members of the public from all pathways, dose conversion factors given in the memorandum, and intake rates of $2.66 \times 10^2 \text{ m}\ell/\text{s}$ for air and $2 \times 10^3 \text{ m}\ell/\text{day}$ for water. (St85)

b. These limitations are presented as indicators of the types of parameters and associated concentration limits required by the NPDES permit. Details of these requirements specific to each discharge location are given in the referenced document. (US84a) The daily and monthly limitations indicated cannot be correlated with the annual water quality data summarized in Table 11.

APPENDIX B

QUALITY CONTROL

A Quality Program Plan and a Quality Control Program Plan have been developed for the Environmental Management (EM) and the Health/Environment Analytical Laboratory (H/EL) Sections, respectively. Independent audits of these plans, coupled with EM's internal environmental audit and controls procedures, ensure that necessary quality assurance and quality control elements exist for a comprehensive environmental monitoring program.

The Quality Program Plan developed by Environmental Management provides controls for assurance that:

- Current operating procedures exist for all phases of EM operations and that these procedures are implemented as written.
- Appropriate approvals are obtained prior to program initiation or change.
- The equipment used in sample collection and data analysis is appropriate to the assigned function and is operating as required.
- Accurate documentation exists for all programs, procedures, and actions.
- All variances from procedures or equipment use and performance are documented and explained with an impact assessment.
- Appropriate guidelines and standards for environmental monitoring are identified, and documentation of compliance is provided on a routine basis to Rocky Flats management, Department of Energy (DOE), and State and Federal regulatory agencies.

The EM Quality Program Plan establishes control points and delineates responsibilities for specific categories of activities; provides an information base from which procedures can be developed, updated, and/or implemented; establishes a state of emergency preparedness in its contingency plans; and provides documented evidence of intent to comply with rules and regulations of Federal, State, and local regulatory agencies.

The plan includes quality assurance flow charts and quality matrices that illustrate activity networks and corresponding quality elements of each responsibility area. A complete listing of activities and responsibilities is also included in the Plan.

To ensure data reliability, the H/EL Quality Control Program Plan outlines the quality control methods used in all phases of laboratory operations.

This quality control program includes the following elements:

- Development, evaluation, improvement, modification, and documentation of analytical procedures.
- Scheduled instrument calibration, control charting, and preventive maintenance.
- Participation in interlaboratory quality comparison programs.
- Intralaboratory quality control programs.

All sample batches scheduled for analysis by the H/EL Central Receiving Laboratory contain an average of 10 percent control samples. The controls consist of analytical blanks prepared in-house and standards prepared by the Rocky Flats Chemistry Standards Laboratory.

An analysis or group of analyses may be rejected and the sample or samples scheduled for reanalysis for one or more of the following reasons:

1. The chemical recovery is less than 10 percent or greater than 110 percent.
2. The analytical blanks in the analysis batch are out of acceptable range.
3. The standards in the analysis batch are not within acceptable limits of error.
4. The alpha energy spectrum is not acceptable because of the following:

- a. extra and/or unidentified peaks.
- b. excess noise in background areas.
- c. poor resolution of peaks.

5. The chemist in charge of the laboratory believes there is reason to suspect the analysis.

Any unusual condition affecting the results, which is noted either during sample collection or analysis, is reported to Environmental Management.

Table B-1 is a summary of H/EL participation in the Rocky Flats Chemistry Standards Laboratory Bioassay and Environmental Measurements Program for 1986.

The H/EL participates in the EPA Environmental Monitoring Systems Laboratory (EMSL) Crosscheck Program. Table B-2 summarizes the H/EL participation in this program.

TABLE B-1. Health/Environment Analytical Laboratory Bioassay and Environmental Measurements Program Data (January Through December 1986)

Isotopes Reported	Matrix	Method	Standard Range	Normal Sample Range	Annual Relative ^a Error Percent	Total Control Analyses
Pu-239, -240	Water	Alpha Spectral	1.2-35 d/m/ℓ	0-3 d/m/ℓ	-1	96
Am-241	Water	Alpha Spectral	0.7-21 d/m/ℓ	0-3 d/m/ℓ	11	90
U-238, -234, -235	Water	Alpha Spectral	3-90 d/m/ℓ	0-30 d/m/ℓ	10	103
H-3	Water	Liquid Scintillation	6000-200,000 pCi/ℓ	0-4500 pCi/ℓ	-7	79
Pu-239, -240	Effluent Filters	Alpha Spectral	4-120 d/m/f	0-30 d/m/f	2	209
Am-241	Effluent Filters	Alpha Spectral	3-90 d/m/f	0-4 d/m/f	2	139
U-238, -234, -235	Effluent Filters	Alpha Spectral	10-300 d/m/f	0-30 d/m/f	7	129
Be ^b	Effluent Filters	Atomic Absorption	0.3-10 µg/f	0-5 µg/f	5	128
Pu-239, -240	Ambient Filter	Alpha Spectral	2-45 d/m/f	0-50 d/m/f	6	87
Be	Workplace Filter	Atomic Absorption	0.3-10 µg/f	0-20 µg/f	4	1325

a. The average of the ratio of the 12-month deviations between observed and standard value to standard value in percent; the relative error for control measurements is often called the coefficient of variation where the dispersion of data (in this case, the average difference between measured and standard values) is divided by the average standard value submitted. This term is inclusive of all random and systematic error in the standards, analytical chemistry, and measurement process for a given nuclide, matrix, and procedure.

b. Analyzed by 881 General Laboratory.

TABLE B-2. Health/Environment Analytical Laboratories Participation in the EPA Environmental Monitoring Systems Laboratory Crosscheck Program During 1986

Isotope Reported	Matrix	Method	Number of Analysis Reported	Average Relative Percent Error*	Average of Normalized Deviation Around Known Value
Gross Alpha	Water	Zinc Sulfide Scintillation Detector	5	-15.6	-0.79
Cr-51	Water	Gamma Spectral	1	-41.8	-8.54
Co-60	Water	Gamma Spectral	1	-32.3	-3.46
Zn-65	Water	Gamma Spectral	1	-25.5	-7.51
Ru-106	Water	Gamma Spectral	1	-35.6	-9.12
Cs-134	Water	Gamma Spectral	2	-23.0	-2.30
Cs-137	Water	Gamma Spectral	2	-19.4	-2.25
H-3	Water	Beta Liquid Scintillation	3	-6.8	-4.06
Pu-239	Water	Alpha Pulse Height	1	+49.1	8.52
U (natural)	Water	Alpha Pulse Height	1	-7.4	-0.19
H-3	Urine	Beta Liquid Scintillation	1	-9.4	-1.62

*Previously reported as the normalized average standard deviation.

APPENDIX C

ANALYTICAL PROCEDURES

The Health/Environment Analytical Laboratories (H/EL) routinely perform the following analyses on environmental and effluent samples:

1. Total Air Filter Counting (Pu specific alpha)
2. Tennelec Air Filter Counting (Gross alpha & gross beta)
3. Gamma Spectral Analysis
4. Alpha Spectral Analysis (Pu-239, -238, Am-241, U-238, -233, -234)
5. Beta Liquid Scintillation (Tritium)
6. N,N-Diethyl-p-phenylenediamine (DPD) (Chlorine)
7. Bacteria
8. Atomic Absorption (Beryllium)

Procedures for these analyses are described in the H/EL Procedures and Practices Manual (Wi82). The procedures for bacteria and chlorine analyses were developed following Environmental Protection Agency (EPA) guidelines. Soil procedures were developed following specifications set forth in "Measurements of Radionuclides in the Environment, Sampling and Analysis of Plutonium in Soil," NRC Reg. Guide 4.5. All new procedures and changes to existing procedures must be thoroughly tested, documented, and approved in writing by the Manager of H/EL before being implemented. Environmental Management is notified of any major changes that could affect analytical results. All procedures are reviewed annually for consistency with state-of-the-art techniques, or at any time an analytical problem is suspected. Copies of all procedures are kept on file in the office of the Manager of H/EL.

The following is a general outline of the analytical procedures followed by the laboratories.

Samples received for air filter screening are counted approximately 24 and 48 hours after collection. Samples exceeding the limits set by Environmental

Management are recounted. If the total long-lived alpha concentration for a screened filter exceeds the EM action limits, the filter is directed for individual specific isotope analysis and/or followup investigation to determine the cause and any needed corrective action.

All water samples, except those scheduled for tritium analysis, are poured into one-liter Marinelli[®] containers and sealed before delivery to the gamma counting area. Routine water samples are counted for approximately twelve hours. Samples requiring a lower detection limit are counted from 16 to 72 hours.

Soil samples scheduled for gamma spectral analysis are dried, sieved through a ten-mesh sieve, weighed, and the fine portion is ball-milled. The fine portion is then placed in a 500-ml Marinelli container and counted for at least 16 hours.

Filter samples scheduled for gamma analysis are placed in petri dishes and counted for approximately 16 hours.

All samples scheduled for alpha spectral analysis are analyzed in a similar manner regardless of matrix. Prior to dissolution, a known quantity of nonindigenous radioactive tracer is added to each sample. The tracer is used to determine the chemical recovery for the analysis. Tracers used include Pu-236, Pu-242, U-232, U-236, Am-243, and Cm-244. The type and activity level of the tracer used depends on the type and projected activity level of the sample to be analyzed. All refractory or intractable actinides are dissolved by vigorous acid treatment using oxidizing and complexing acids.

After samples are dissolved, the radioisotopes of concern are separated from each other and from the matrix material by various solvent extraction and ion exchange techniques. The purified radioisotopes are electrodeposited onto stainless steel discs. These discs are alpha counted for a minimum of 16 hours. If a lower minimum detection limit is required samples may be counted from 72 to

168 hours depending upon the need. Samples that exhibit a chemical recovery of less than 10 percent or greater than 110 percent are automatically scheduled for reanalysis.

Tritium analyses are routinely performed on specified environmental water samples as well as stack effluent samples. Five milliliters of the samples are combined with 17 milliliters of liquid scintillation cocktail mixture. Environmental samples are counted for 60 minutes and airborne effluent samples are counted for 10 minutes.

The General Laboratory routinely performs the following analyses for environmental monitoring of plant effluent streams, process wastes, and soil residues:

1. Dissolved metallic elements including tests for 31 cations by emission spectroscopic techniques, and 17 elements by atomic absorption techniques (including beryllium in airborne effluent sample filters).
2. Oxygen demand tests, including total organic carbon, dissolved oxygen, chemical oxygen demand, and biological oxygen demand (5 day incubation).
3. Nutrient tests including free ammonia and amines, ortho and total phosphate phosphorus, nitrate and nitrate anions, Kjeldahl nitrogen, and total nitrogen.
4. Physical tests, including pH, conductivity, color, total dissolved solids, suspended solids, turbidity, and specific gravity.
5. Soap residues (as alkyl sulfonate).
6. Oil and grease residues, by extraction and infrared or gravimetric detection, and by visual observation.
7. Specific chemical property or element, including total hardness (as calcium carbonate), alkalinity (as hydroxide, bicarbonate, or carbonate), chloride, fluoride, cyanide, sulfate, and hexavalent chromium.
8. Radioactive species, including gross alpha and beta by gas proportional detection; tritium by liquid scintillation detection; radium, cesium-134, and strontium-89 or -90 by gravimetric separation followed by gas proportional detection. Isotopes of plutonium, americium, thorium, uranium, neptunium, and curium are determined by ion exchange and liquid extraction techniques followed by alpha pulse height analysis.
9. Organic toxic species, including Bromacil, Endrin, Lindane, methoxychlor, toxaphene, phenol, polychlorinated-biphenyls, 2,4-D, 2,4,5-TP Silvex, and total organic halogen.

Procedures for these analyses were developed by the General Laboratory professional technical staff. Procedures were adopted from EPA-approved sources or from other recognized authoritative publications where EPA-approved procedures were not available. Laboratory operational procedures are documented in a standard format, approved by the manager of the Rocky Flats Analytical Laboratories, and distributed to a controlled distribution list to assure that proper testing and approval is performed before changes are adopted. The General Laboratory Quality Assurance Plan requires annual review of procedures for consistency with state-of-the-art techniques and compliance of laboratory practice with written procedures. In addition, a review is performed whenever an analytical problem is indicated.

The following is a general outline of the analysis procedures followed by the General Laboratory:

All water samples which are analyzed for radioactive materials - except those scheduled for tritium analysis - are acidified immediately upon collection.

Liquid samples received for gross alpha and beta screening are evaporated directly onto planchets for gas proportional counting within 24 hours of collection. When activities exceeding the action guidelines set by Environmental Management (EM) are observed, notification to EM is made, and reanalysis is begun immediately for verification.

For some liquids such as machine oils, a specified volume is evaporated and the residue is taken up in dilute nitric acid for deposit onto the counting planchet. A correction factor is determined for each sample to account for self-absorption effects.

Liquid and solid samples submitted for alpha spectral pulse height analysis are analyzed in a manner similar to procedures followed by H/EL. Chemical separation of elements is followed by deposition of an organic extract of 2-Thenoyltrifluoroacetone (TTA) complex onto a planchet for pulse height analysis of the alpha energy spectrum.

Water samples to be tested for chemical and physical parameters are analyzed within 24 hours of collection, or they are preserved by refrigeration, freezing, or addition of a chemical preservative when required. The tests performed include gravimetric, titrametric, colorimetric, chromatographic, or electroanalytical methods, following procedures specified in the 15th edition of Standard Methods for the Examination of Water and Waste Water, EPA-600/4-79-020, or other authoritative publications.

Water samples to be analyzed for dissolved metallic ions are filtered through a 4.5 micron filter and evaporated onto a graphite electrode for emission spectrographic analysis. Selected elements are determined for sample solutions by atomic absorp-

tion methods after appropriate chemical treatment to prepare the proper analysis matrix.

Organic toxic species are determined by chromatography, following extraction into an appropriate organic solvent or onto a solid resin, using flame ionization, electron capture, or ultraviolet detection. Some organics, such as phenol, are determined by developing a chromaphoric complex and measuring light absorption at a specific wavelength with a spectrophotometer. Measuring occurs after extraction into an appropriate solvent phase.

Tritium is determined by intimate mixing of five milliliters of aqueous sample (or of water that has equilibrated with the sample for a predetermined time to ensure exchange) with 17 milliliters of scintillation cocktail. The mixture is counted for 20 minutes in a scintillation well, and a correction factor is applied to account for quenching effects determined in situ for each sample.

Cesium, radium, and strontium isotopes are radiochemically separated from the sample matrix using precipitation techniques. Cesium, strontium, and some radium isotopes are deposited on planchets with a carrier element for alpha or beta gas proportional counting. Radium-226 is counted directly measuring the radon-222 emanation in a scintillation well by using a Lucas gas collection cell.

APPENDIX D

DETECTION LIMITS AND ERROR TERM PROPAGATION

The Rocky Flats Health/Environment Analytical Laboratories (H/EL) have adopted the following definition for detection limit, as given by Harley.(Ha72)

“The smallest amount of sample activity using a given measurement process (i.e. chemical procedure and detector) that will yield a net count for which there is confidence at a predetermined level that activity is present.”

The minimum detectable amount (MDA) is the term used to describe the detection limit and is defined as the smallest amount of an analytic material in a sample that will be detected with a β probability of non-detection (Type II error), while accepting an α probability of erroneously detecting that material in an appropriate blank sample (Type I error). At the 95% confidence level, both α and β are equal to 0.05.

Based on the approach presented in draft ANSI standard N13.30 “Performance Criteria for Radiobioassay,”(He85) the formulation of the MDA for radioactive analyses is:

$$\text{MDA} = \frac{4.65 S_B + 3/(T_S E_S Y)}{aV}$$

where S_B = standard deviation of the population of appropriate blank values (d/m)

T_S = sample count time (m)

E_S = absolute detection efficiency of the sample detector

Y = chemical recovery for the sample

a = conversion factor (d/m per unit activity)

($a = 2.22 \text{ d/m/pCi}$ when MDA is in units of pCi and

$a = 2.22 \times 10^6 \text{ d/m/}\mu\text{Ci}$ when MDA is in units of μCi)

V = sample volume or weight

($V=1$ if the MDA per sample is desired.)

The major component of the MDA equation is the variability of the blanks.

Table D-1 shows the various formulae used for alpha data reduction during 1986.

Table D-2 shows the typical MDA values for the various analyses performed by the H/EL and by the General Laboratories. These values are based on the average sample volume, typical detector efficiency, detector background, count time, and chemical recovery. MDA values calculated for individual analyses may vary significantly depending on actual sample volume, chemical recovery, and analytical blank used.

For nonradioactive parameters, various means are used to estimate a minimum detectable amount depending on the parameter measured. The minimum detectable amount for beryllium in effluent air - analyzed using flameless atomic absorption spectroscopy - is based on a sample absorbance reading of 0.010 above the sample blank absorbance reading. Total chromium in effluent water samples undergoes a four-fold concentration of the received sample prior to its analysis using flame atomic absorption spectroscopy. Its approximate minimum detectable amount is based on a net sample absorbance reading of 0.010.

The parameters of nitrate as N, total phosphorous, suspended solids, oil and grease, and total organic carbon all have minimum detectable amounts that are determined by procedural methods found in EPA-600, “Methods for Chemical Analysis of Water and Wastewater.”(US79) The parameters of pH and Biochemical Oxygen Demand have minimum detectable amounts that are determined by the minimal readout capability of the instrumentation that is used.

The minimum detectable amount for residual chlorine is determined by the procedure found in a publication by Hach Co., “DPD Method for Chlorine.”(Ha83) For fecal coliform count, the minimum detectable amount is calculated as 4.65 times the standard deviation of the blank value from the millipore filter.

TABLE D-1. Formulae for Activity and Uncertainty Calculations for the Alpha Spectral Analysis Systems

Non-Blank Corrected Sample Uncertainty*

$$a_{si} = A_{si} \left[\frac{\frac{C_{si}}{T_s^2} + \frac{C_{Bi}}{T_B^2}}{\left(\frac{C_{si}}{T_s} - \frac{C_{Bi}}{T_B}\right)^2} + \frac{\frac{C_{sj}}{T_s^2} + \frac{C_{Bj}}{T_B^2}}{\left(\frac{C_{sj}}{T_s} - \frac{C_{Bj}}{T_B}\right)^2} \right]^{1/2}$$

Blank Corrected Sample Uncertainty

$$b_{si} = (a_{si}^2 + a_{ri}^2)^{1/2}$$

Non-Blank Corrected Sample Activity

$$A_{si} = \left[\frac{\frac{C_{si}}{T_s} - \frac{C_{Bi}}{T_B}}{\frac{C_{sj}}{T_s} - \frac{C_{Bj}}{T_B}} \right] \cdot \frac{D_{sj}}{V \cdot 2.22}$$

Blank Corrected Sample Activity

$$B_{si} = A_{si} - A_{ri}$$

*Corrected from 1984 report.

(continued)

TABLE D-1. (Concluded)

Legend

A_{ri}	=	Non-blank corrected activity of laboratory reagent blank for isotope i, expressed as picocuries per unit volume.
a_{ri}	=	Non-blank corrected uncertainty of laboratory reagent blank, expressed as picocuries per unit volume.
A_{si}	=	Sample activity for isotope i, expressed as picocuries per unit volume.
a_{si}	=	Sample activity uncertainty, expressed as picocuries per unit volume.
B_{si}	=	Blank corrected sample activity for isotope i, expressed as picocuries per unit volume.
b_{si}	=	Blank corrected sample uncertainty, expressed as picocuries per unit volume.
C_{Bi}	=	Detector background gross counts for isotope i.
C_{Bj}	=	Detector background gross counts for internal standard isotope j.
C_{si}	=	Sample gross counts for isotope i.
C_{sj}	=	Sample gross counts for internal standard isotope j.
D_{sj}	=	Activity (disintegrations per minute) of internal standard isotope j added to sample.
T_B	=	Detector background count time expressed in minutes.
T_s	=	Sample count time expressed in minutes.
V	=	Sample unit volume or sample unit weight.

TABLE D-2. Detection Limits for Radioactive and Nonradioactive Materials

Legend			
μCi = microcuries		pCi = picocuries	
μg = micrograms		mg/l = milligrams per liter	
m^3 = cubic meters		SU = standard units	
mℓ = milliliters			
Parameter	Minimum Detectable Amount (per sample)	Approximate Sample Volume Analyzed ^a	Minimum Detectable Amount (per unit volume or mass)
<u>Airborne Effluent Samples</u>			
Plutonium 239, 240	$2.7 \times 10^{-7} \mu\text{Ci}$	7,340 m^3 ^b	$0.04 \times 10^{-15} \mu\text{Ci}/\text{m}\ell$
Uranium 233, 234, 238	$4.5 \times 10^{-7} \mu\text{Ci}$	7,340 m^3 ^b	$0.06 \times 10^{-15} \mu\text{Ci}/\text{m}\ell$
Tritium	$5.5 \times 10^{-6} \mu\text{Ci}$	1.4 m^3	$3,900 \times 10^{-15} \mu\text{Ci}/\text{m}\ell$
Beryllium	$2.5 \times 10^{-1} \mu\text{g}$	7,340 m^3 ^b	$5 \times 10^{-5} \mu\text{g}/\text{m}^3$
<u>Ambient Air Samples</u>			
Plutonium 239, 240	$8.0 \times 10^{-7} \mu\text{Ci}$	29,000 m^3 ^c	$0.003 \times 10^{-15} \mu\text{Ci}/\text{m}\ell$
<u>Effluent Water Samples (Radioactive)</u>			
Plutonium 239, 240	$5.1 \times 10^{-8} \mu\text{Ci}$	5,000 mℓ	$0.02 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$ ^c
Uranium 233, 234, 238	$1.5 \times 10^{-7} \mu\text{Ci}$	1,000 mℓ	$0.15 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$
Americium 241	$1.5 \times 10^{-7} \mu\text{Ci}$	5,000 mℓ	$0.03 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$ ^c
Tritium	$3.2 \times 10^{-6} \mu\text{Ci}$	5 mℓ	$1,400 \times 10^{-9} \mu\text{Ci}/\text{m}\ell$
<u>Soil Samples (Radioactive)</u>			
Plutonium 239, 240	$3.7 \times 10^{-7} \mu\text{Ci}$	10 g	$3.7 \times 10^{-8} \mu\text{Ci}/\text{g}$
<u>Effluent Water Samples (Nonradioactive)</u>			
pH		100 mℓ	0-14 SU
Nitrate as N		10 mℓ	0.2 mg/l
Total Phosphorus		50 mℓ	0.2 mg/l
Biochemical Oxygen Demand, 5-Day		300 mℓ	5.0 mg/l
Suspended Solids		100 mℓ	1.0 mg/l
Total Chromium		100 mℓ	0.05 mg/l
Residual Chlorine		10 mℓ	0.1 mg/l
Oil and Grease		1,000 mℓ	0.5 mg/l
Fecal Coliform Count		10-100 mℓ	43 organisms/100 mℓ
Total Organic Carbon		5 mℓ	1.0 mg/l

a. Volume analyzed is usually an aliquoted fraction of the total sample volume collected.

b. Monthly composite.

c. Composite of two bi-weekly samples.

APPENDIX E

REPORTING OF MINIMUM DETECTABLE CONCENTRATION AND ERROR TERMS

Throughout the section entitled "Monitoring Data: Collection, Analyses, and Evaluation" in this report, some of the concentrations that are measured at or below the minimum detectable concentration (MDC) are assigned the MDC value. The less-than symbol (<) indicates MDC values and calculated values that include one or more MDCs.

The plutonium, uranium, americium, and beryllium measured concentrations are reported. These reported concentrations include values that are less than the corresponding calculated MDCs and in some cases, values less than zero. Negative values result when the measured value for a laboratory reagent blank is subtracted from an analytical result that was measured as a smaller value than the reagent blank. These resulting negative values are included in any arithmetic calculations on the data set.

Error terms in the form of $a \pm b$ are included with some of the data. For a single sample, "a" is the reagent-blank corrected value; for multiple samples it represents the average value (arithmetic mean). The error term "b" accounts for the propagated statistical counting uncertainty for the sample and the associated reagent blanks at the 95 percent confidence level. These error terms represent a minimum estimate of error for the data. Other analytical and sampling errors are being investigated for future incorporation into an all-inclusive error term for each value.

Ninety-five percent confidence limits for the plutonium concentrations in ambient air have been derived using Fieller's Theorem.(Fi78) These limits consist of a Lower Confidence Limit (LCL) and an Upper Confidence Limit (UCL) on each point estimate for the various concentrations. The calculation of the limits requires knowledge of the analytical error term "b" as described above, and in addition, the variance of the air volume measurement associated with a specific sample. These variances are calculated from the data reported as part of a routine flow measurement calibration program for ambient air samplers. Bias errors and temperature coefficients of the sampler readout devices are also statistically computed, and the individual readout devices are individually corrected for those factors.

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